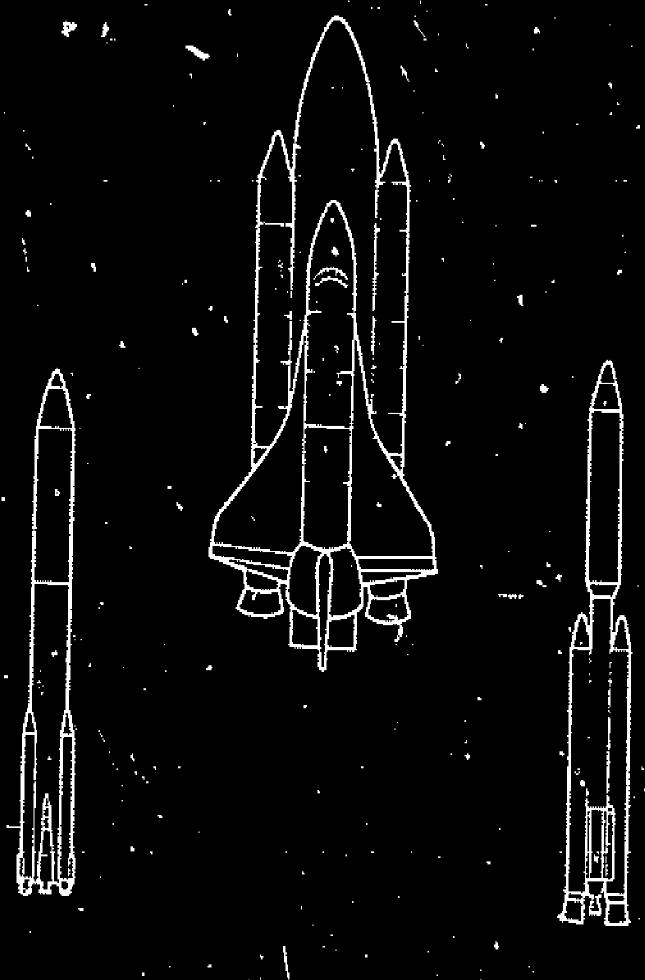
COMPLEMENTARY SPACE LAUNCH STRATEGY FOR ASSURED ACCESS TO SPACE



10 FEBRUARY 1984

COMPLEMENTARY SPACE LAUNCH STRATEGY

FOR

ASSURED ACCESS TO SPACE

GEOSYNCHRONOUS MISSIONS

10 FEBRUARY 1984

HEADQUARTERS SPACE DIVISION
AIR FORCE SYSTEMS COMMAND (AFSC)
United States Air Force
P.O. Box 92960, Worldway Postal Center
Los Angeles, California 90009

APPENDIX

10 February 1984

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I - INTRODUCTION

DOD space systems have become essential elements of the operational systems which provide for National Security. In recognition of this, national policy is to maintain assured access to space (NSDD 85). Consequently, the SecDef in submitting his recent Defense Space Launch Strategy to the President established DOD Space Policy calling for a complementary launch system to the Shuttle to provide "...high confidence of access to space..." This capability is "...needed for all levels of conflict to meet the requirements of national security missions." In the past this requirement was satisfied with a family of expendable launch vehicles, which while not completely assuring access to space for all critical missions, did have the attribute that not all national space missions were reliant on a single model launch vehicle. Thus, a generic grounding of one member of the family of launch vehicles did not necessarily restrict access to space for the launch fleet. The DOD is fully committed to the utilization of the Space Transportation System (STS) as its primary access to space. However, the production of orbiters is currently phasing down with completion of the fourth orbiter. At the same time, production of all U.S. Expendable Launch Vehicles (ELVs) used by major DOD payloads is coming to an end. This situation is inconsistent with the requirement for assured access to space.

Prior analyses of the ELV alternatives indicated that DOD costs to achieve this capability were unacceptable because the alternatives required early high level funding and the recurring costs per launch were higher than STS costs based on the DOD-NASA agreement for flight charges then in effect.

While costs should not be the single criterion for determining national access to space, a recent national policy statement has changed the situation sufficiently that a reassessment of DOD's position on the subject is warranted. This policy (NSDD 94) stated that the U.S. Government should support commercialization of Expendable Launch Vehicles; and, by 1988, it is the Government intent to charge full Shuttle launch costs to users. When the policy is combined with recent proposals by commercial launch vehicle contractors to use their funds for the development of upgraded versions of existing vehicles, the problem to DOD of providing significant near term funding is alleviated. The intent to charge full Shuttle launch costs could lead to a significant increase in cost per flight to DOD for the STS starting in 1988.

This report examines alternative complementary launch systems which include commercial ELVs and a Shuttle derivative vehicle for support of

near-term DOD geosynchronous missions. While the Air Force has concentrated on the potential use of the commercial ELVs, NASA has investigated the concept of a Shuttle derivative vehicle, SRB-X (Solid Rocket Booster-X). For any of these launch systems to be of benefit to the DOD they must offer a capability equivalent to that of the STS, i.e., a performance capability of 10,000 pounds to geosynchronous orbit and 11,500 pounds to 12-hour elliptical orbit, with a payload volumetric capability of 15 feet diameter and 40 feet in length.

Current ELVs which meet commercial user requirements, do not meet either the DOD performance or volumetric requirements discussed above. Therefore, for these vehicles to be of use to the DOD they must be upgraded. Discussion with the manufacturers indicates that commercial development of these upgraded vehicles requires assurance that the DOD will purchase no less than two vehicles per year for a five year period (10 vehicles total production and launch). These vehicles will provide a Shuttle equivalent capability, have their development cost amortized over the total vehicle buy, and be paid for on a per-flight basis with payment in January of the year preceding their launch (identical to the Shuttle payment schedule). Commercial ELVs with the potential for growth to a Shuttle equivalent capability are the $T34D_7$/Centaur G' and the Atlas II/Centaur G'. Both manufacturers, Martin Marietta and General Dynamics, have indicated willingness to enter into such an agreement and are currently under Air Force contract to complete a commercial ELV concept defininition study to define technical, cost, and procurement risks.

An alternative to the commercial ELV complement to the Shuttle, investigated by NASA, is a Shuttle derivative vehicle -- the SRB-X. This vehicle utilizes existing Shuttle components. Although this concept is projected to have a significantly higher cost, this vehicle continues to be studied.

This report contains a summary of the capabilities and costs of both the commercial ELVs and the SRB-X. Included for the commercial ELVs and the SRB-X is an assessment of technical, schedule, and cost risks involved in their procurement and operational capability. Also included is a cost comparison of their use in a Shuttle complementary scenario vis-a-vis a Shuttle only scenario. A comparison of the SRB-X in such a scenario was not performed due to its potential high cost and questions as to its timely availability. Study of this alternative will continue.

The launch date requirement against which these vehicles were aimed was early FY89 with an early FY85 go-ahead. A summary of the technical

and programmatic assessment of these vehicles and the commercial ELV economic comparision with the Shuttle follows.

II - CANDIDATE SYSTEMS

Candidate complementary launch systems include the $T34D_7$/Centaur G', the Atlas II/Centaur G', and the SRB-X. A summary description of these vehicles and their capabilities, accompanied by an assessment of their technical and schedule risks, is presented.

A. $T34D_7$/Centaur G'

1. Both the $T34D_7$ and the Centaur G' are adaptations of vehicles that are currently operational. The modifications required to transform the T34D to the $T34D_7$ include the growth of the solid rocket motors (SRMs) from 5-1/2 segments to seven segments and the stretching of both Stages I and II (Figure II-1).

2. The $T34D_7$ draws heavily from its predecessor Titans. The SRMs are the same as used on current Titan programs except they are lengthened to seven segments. This does not represent a major change as four seven segment motor firings were conducted in 1969 and 1970 for the Manned Orbiting Laboratory (MOL) Program. Stages I and II are the same, including engines, as used on current Titan programs except that fuel and oxidizer tanks in both stages are lengthened. The interstage adapter between Stages I and II is strengthened to accommodate the stretched vehicle. The Stage II forward skirt is modified for higher loads and to accommodate installation of the avionics trusses and equipment. The avionics hardware (guidance, flight controls, electrical, instrumentation, tracking, and flight safety ordnance) to be used on the core vehicle is all of existing design with proven flight history. Cabling will be modified as necessary to accommodate the vehicle configuration. Software currently on the T34D Transtage program will be utilized to the maximum extent practical. The Titan guidance systems will be used to fly the vehicle from liftoff to Stage II/Centaur separation. Minor software changes will be necessary to accommodate vehicle checkout and launch requirements.

Titan 34D7 / Centaur

- 7 SEGMENT SRM's
- STRETCHED STAGE I AND II
- 200 IN PAYLOAD FAIRING
- CENTAUR G' UPPERSTAGE

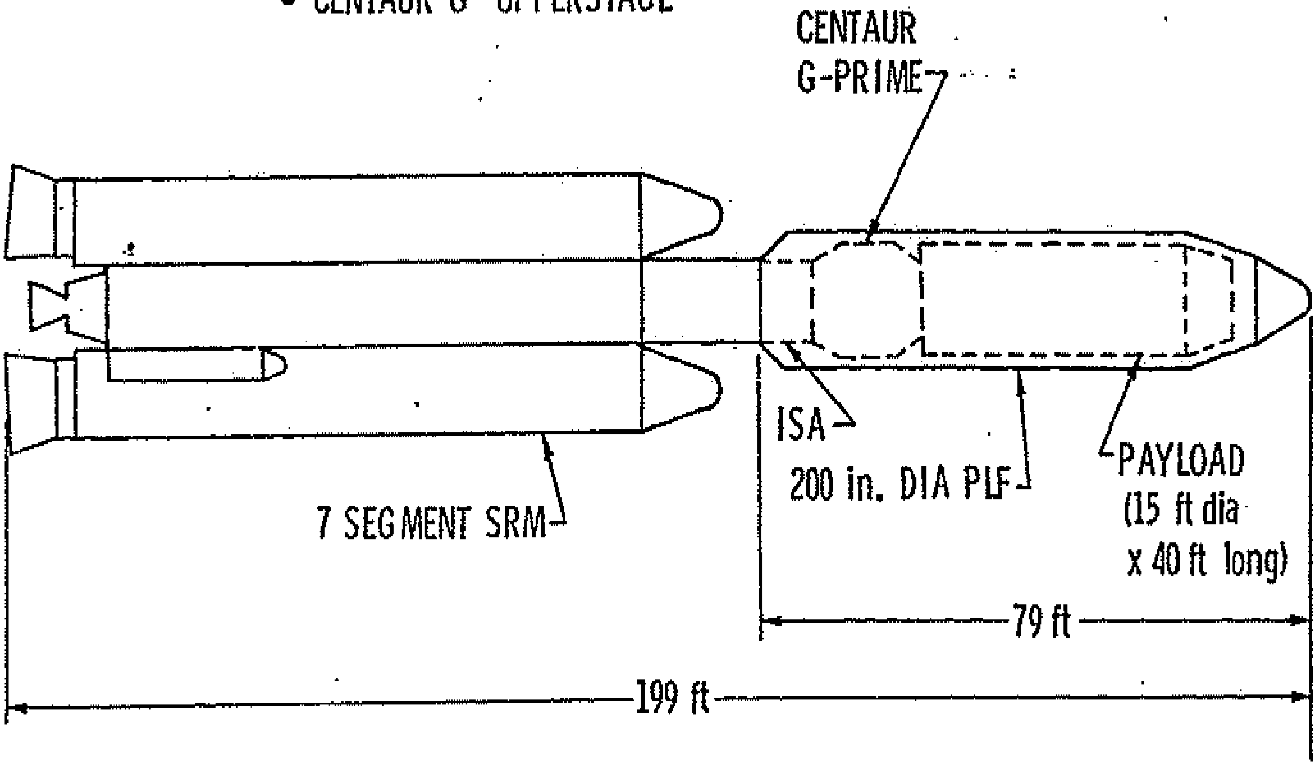


FIGURE II-1

3. The Centaur G' (Figure II-2) is a growth modification of the currently operational D-1T and is scheduled for first launch on the Shuttle in 1986 (NASA planetary missions - Galileo and International Solar Polar). Modifications to the Centaur G' vehicle are to provide the Centaur G payload interface, strengthen the Centaur front end structure to carry the 11,500 pound weight, remove Shuttle-peculiar weight, and add range safety and security equipment.

4. The T34D$_7$ Stage II will mate with the Centaur G' and the payload fairing through an interstage adapter similar to that used for the highly successful Titan IIIE/Centaur program that flew NASA planetary missions during the 1970s. A 200 inch diameter payload fairing of new design will shroud the Centaur and payload. However, the fairing is not without precedence since a large diameter type fairing (14 foot) was launched successfully on the Titan IIIE/Centaur program, and several studies have been conducted on the use of the 200 inch diameter design.

5. The T34D$_7$/Centaur G' launch is planned from Launch Complex 41 at Cape Canaveral Air Force Station, Florida. The effort required to install and launch the vehicle can be grouped into two categories: the refurbishment needed for reactivation of the complex and the modifications necessary to convert from a Titan IIIE/Centaur configuration to the T34D$_7$/Centaur G' configuration.

6. Detailed trajectory simulations for the geosynchronous orbit mission and the 12-hour elliptical orbit mission were made by Martin Marietta and verified by the Aerospace Corporation. These simulations demonstrate that the proposed T34D$_7$/Centaur G' will deliver a spacecraft weight of 10,200 pounds to the geosynchronous orbit and 11,500 pounds to the 12-hour elliptical orbit. The 12-hour elliptical orbit performance might be improved to 15,000 pounds with a strengthening of the Centaur structure.

Modified Centaur G-Prime Vehicle

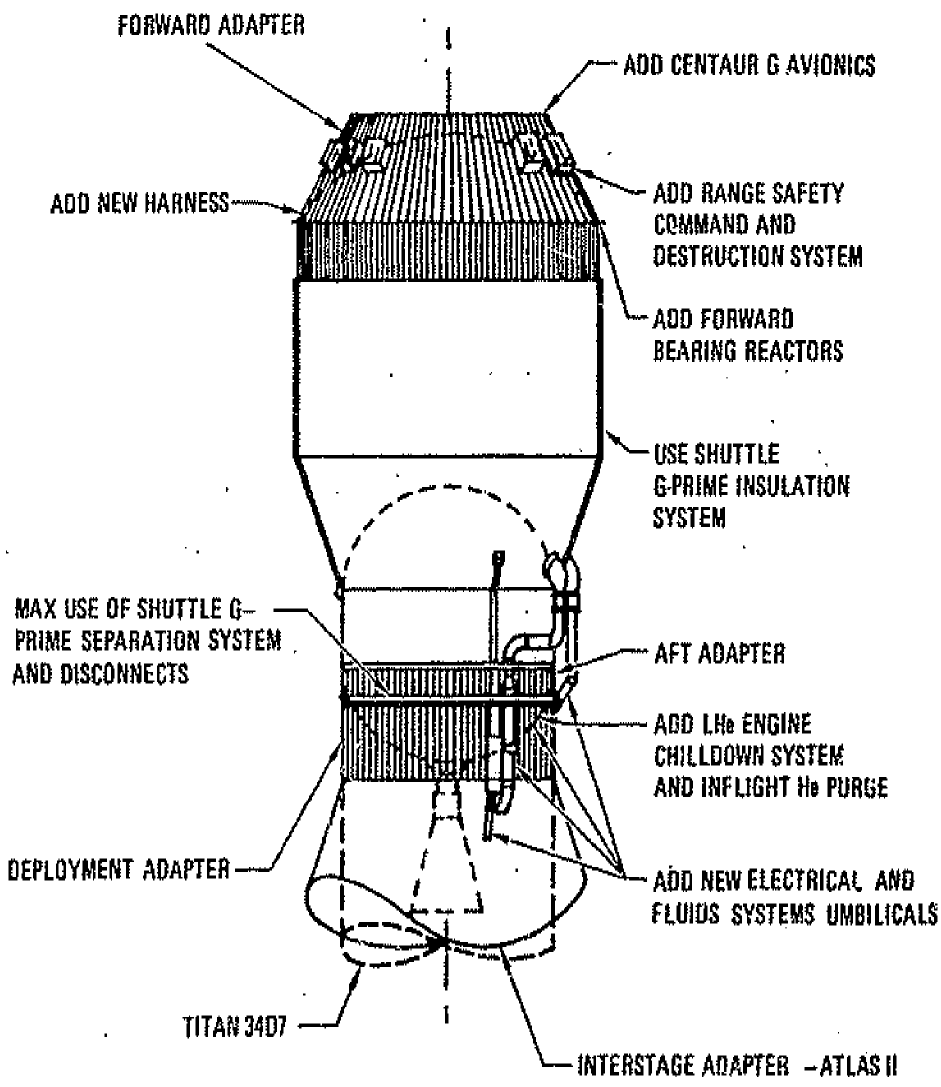


FIGURE II-2

7. The development schedule for the $T34D_7$/Centaur G' provides for an Initial Launch Capability (ILC) of 1 October 1988 with development initiated 1 October 1984. This four year development schedule is considered conservative and affords several months for contingencies.

8. The technical and schedule risks for $T34D_7$/Centaur G' to meet performance, operational, and schedule requirements have been assessed as being low.

B. Atlas II/Centaur G'

1. The Atlas II/Centaur G' represents a modification to the currently operational Atlas G and the Centaur D-1T. The selected configuration is a growth version of the Atlas II/Centaur vehicle which has been studied by General Dynamics over the past several years for launch of commercial satellites. The Atlas II (Figure II-3) being proposed is a vehicle 200 inches in diameter with a propulsion system consisting of five liquid rocket engines (LREs), four solid rocket motors (SRMs), and two roll control modules (RCMs). The SRMs are jettisoned at launch + 100 seconds. At booster stage cutoff, four LREs are jettisoned and the RCMs are activated to provide roll control through the sustainer flight phase. The Atlas II booster thrust structure is similar to the current Atlas system. The basic difference is its 200 inch diameter that must react with the propulsive thrust loads from the four booster engines and the four solid rocket motors on the aft end and with greater aerodynamic and inertia loads. The current Atlas diameter is 120 inches. It has two booster, one sustainer, and two vernier engines; and no solid rocket motors. Three liquid engine candidates have been investigated for the Atlas II: Rocketdyne H1-D, Rocketdyne RS-27, and Aerojet engines.

Atlas II / Centaur Configuration

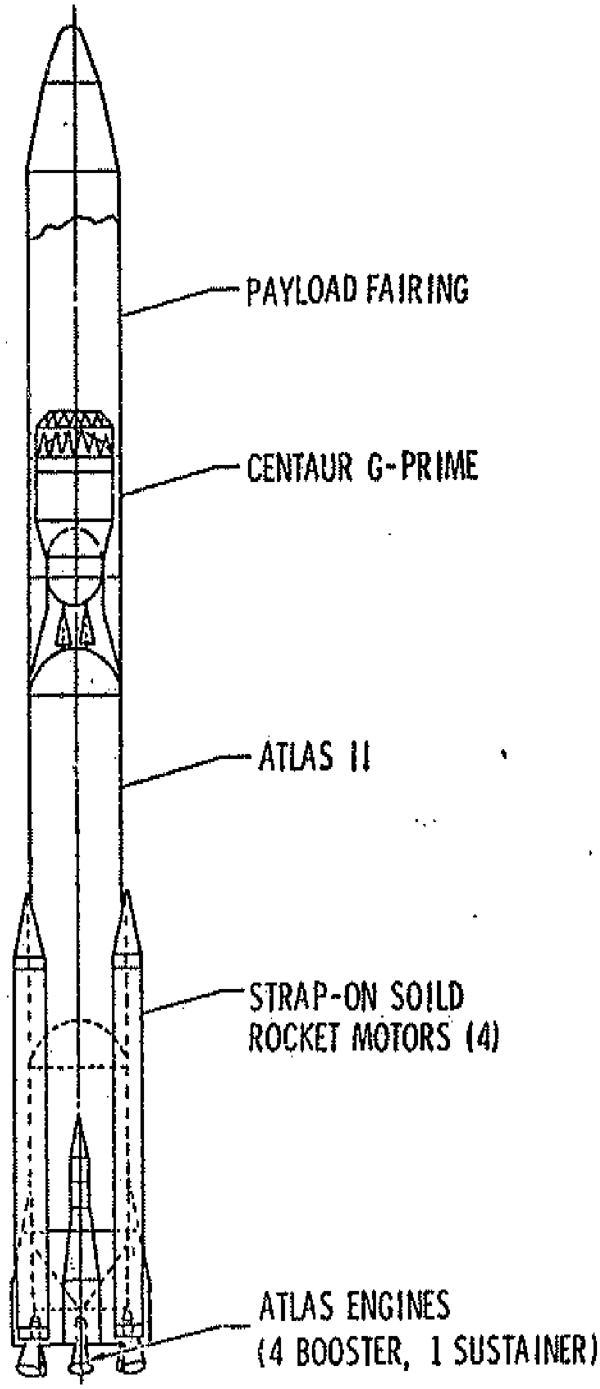


FIGURE II-3

2. The modifications required to the Centaur G' for its use on the Atlas II are similar to those required for the $T34D_7$. (Section IIA-3).

3. The payload fairing will be a new 200 inch diameter metallic structure built to accommodate payloads with a maximum envelope diameter of 15 feet, consistent with that available in the Space Shuttle. The fairing will have openings, environmental seals, a forward bearing reactor system, and disconnects similar to those used on previous Titan IIIE missons flown with a 14 foot fairing.

4. The Atlas II/Centaur G' is planned for launch from Launch Complex 41. As with the $T34D_7$/Centaur G', this complex will require both renovation and modification to support the specific vehicle characteristics.

5. In order to provide a performance margin, the vehicle was sized for an 11,000 pound (1,000 pound margin) geosynchronous payload capability. A baseline reference trajectory was developed and the quoted performance capability was based on an assumed set of trajectory design groundrules and constraints as well as mass property estimates. The 12-hour elliptical orbit capability exceeds 15,000 pounds but the Centaur is structurally constrained to 11,500 pounds as previously explained.

6. The development schedule for the Atlas II/Centaur G' could provide an Initial Launch Capability (ILC) of 1 October 1988 with development initiated on 1 October 1984.

7. The technical risks for the Atlas II/Centaur G' meeting the performance and operational requirements have been assessed as moderate. Because of the extensive modifications to the vehicle necessary to provide this performance capability, there is concern that technical problems may result in a schedule slip. The schedule risk is associated primarily with liquid engine deliveries late in the program which causes the engine cluster firing and integrated feed system demonstration to occur only a few months prior to Initial Launch Capability. The lack of solid and liquid engine ignition sequence, thrust buildup, thrust differential and overpressure data introduces some uncertainty in vehicle and spacecraft loads. The schedule risk is accordingly assessed as moderate.

C. SRB-X/Centaur G'

1. The SRB-X is a Shuttle derivative vehicle configured by the Boeing Aerospace Corporation for NASA/MSFC (Figure II-4).

2. The SRB-X concepts are based on utilization of the STS Solid Rocket Booster and solid rocket motor technology in combination with other existing stages for a building block Shuttle derived family of launch vehicles. The contractor studies of these concepts identified a four-stage configuration for geosynchronous missions which is a combination of Shuttle solid rocket technology with Titan and Centaur liquid rocket stages. The selected SRB-X concept consists of the following elements:

Stage 1	- 2-4 Segment STS SRBs
Stage 2	- 1-2 Segment Modified STS SRB
Stage 3	- 1 - Titan 34D Stage 2 (Liquid System)
Stage 4	- 1 - Centaur
Payload Fairing	- Large diameter for a 15 ft dia x 40 ft length payload

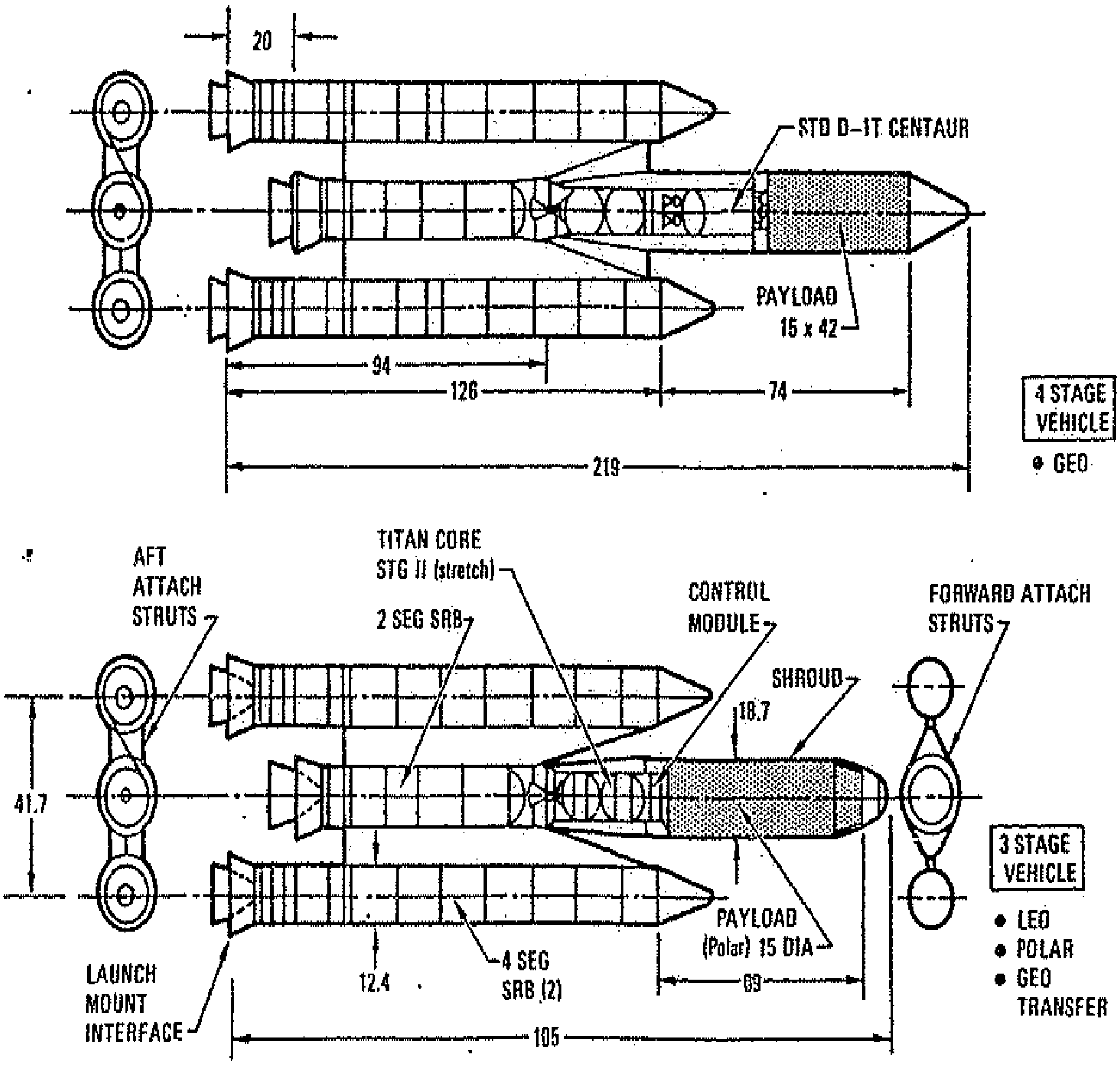
This vehicle has a geosynchronous performance capability of 12,000 pounds. Gross liftoff weight is 3,440,000 pounds.

3. The SRB-X concept is designed to be compatible with processing through the existing Shuttle launch facilties and ground operations with as little modification or interference as possible. The SRB-X SRBs are spaced 41.7 feet apart to coincide with the STS launch pad's SRM exhaust ducts. The second, third, and fourth stages are suspended by truss structures between the two SRBs. Launch pad modifications are required for handling and loading of the liquid stages with storable and cryogenic propellants. Furthermore, since SRB-X will require use of Shuttle facilities which are configured for a 24 per year Shuttle launch capability, creating an SRB-X complement to Shuttle may require facility enhancements.

4. A large diameter payload fairing of new design will shroud the Centaur/payload.

5. The SRB-X configuration is the result of concept exploration studies and represents a very preliminary engineering configuration. Based upon the data from the NASA study, it is felt that the ability to meet either an October 1984 development start or an October 1988 Initial Launch Capability is highly improbable. However, the concept is being studied to further assess its potential.

SRB-X Vehicle General Arrangement



NOTES:
- FIRST 3 STAGES IDENTICAL
- ALL DIMENSIONS IN FEET

FIGURE II-4

III - COST OF CANDIDATES

The development and operations costs for the candidate vehicles reflect contractor cost estimates modified by Government analysis. Added to these costs are estimates of Government support and range costs. Cost estimates for the three candidate vehicles are based upon differing levels of input data fidelity and are addressed accordingly.

A. $\underline{T34D_7\text{/Centaur G'}}$

1. The cost-per-flight for the $T34D_7$/Centaur G' has been estimated at approximately $170 million FY83 dollars. This cost is composed of a $115 million FY83 dollar cost per launch of the $T34D_7$ and a $55 million cost per launch of the Centaur G'. The $115 million FY83 dollar cost per flight of the $T34D_7$ is composed of a $160 million development cost amortized over a ten vehicle buy, a recurring cost per flight of $90 million, and a cost of money addition of $9.3 million per vehicle. This cost is based upon a production rate of four vehicles per year, a launch rate of two vehicles per year, and a total buy of ten vehicles. The costs have been structured to maintain a production capability through the five year launch period by the retention of critical skills and facilities. These costs were assessed to be both reasonable and complete.

2. The Centaur G' cost per flight of $55 million FY83 dollars is composed of a development cost of $64 million FY83 dollars amortized over a ten vehicle buy, a recurring cost per flight of $45.3 million and a cost of money addition of $3.3 million per vehicle. These costs assume the Centaur G' is provided separately from the $T34D_7$. While we have not made an element by element analysis of Centaur costs, the historical data base combined with NASA's recent quote of $50 million as the per launch cost of a Shuttle/Centaur gives confidence that the $55 million launch cost used in this study is reasonable.

B. <u>Atlas II/Centaur G'</u>

1. The cost per flight of the Atlas II/Centaur G' has been estimated at $207 million FY83 dollars. This cost is composed of a $160 million FY 83 dollar cost per launch for the Atlas II and a $47 million FY 83 dollar cost per launch for the Centaur G'. The $160 million FY83 dollar cost per flight of the Atlas II is composed of a $452 million development cost amortized over a ten vehicle buy, a recurring cost per flight of $96.8 million, and a cost of money addition of $18.3 million. While sufficient data

was not available to make an element-by-element analysis, an assessment from historical data for a smaller Atlas indicates that both the non-recurring and recurring cost may be overstated.

2. The Centaur G' cost per flight of $47 million FY83 dollars is composed of a development cost of $63 million FY83 dollars amortized over a ten vehicle buy, a recurring cost per flight of $36.9 million, and a cost of money addition of $3.3 million. This cost assumes that the Centaur G' is procured on the same contract as the Atlas II due to the common manufacturer. This explains the lower Centuar G' cost per flight when used with the Atlas II versus the $T34D_7$. Again, while sufficient data is not available at this time for an element-by-element analysis, this cost is believed to be complete and reasonable.

C. SRB-X/Centaur G'

1. The estimated cost per flight of the SRB-X/Centaur G' data is $257 million FY83 dollars. This cost includes a development cost of $743 million FY83 dollars amortized over a ten vehicle buy, a recurring cost per flight of $133 million and a Centaur recurring cost per flight of $50 million. These costs are based upon the NASA funded study supplemented to provide for Government launch support and range operations. These costs appear reasonable to a first approximation, but are for a Government development program. A commercial development would add the cost of money to the above costs.

The Centaur cost is $5 million less than the figure quoted for the Centaur used on $T34D_7$ because no cost of money ($3 million) is included. The NASA study did not consider the SRB-X to be a commercial procurement. Also, $2 million of amortized launch pad modification costs are not required since any pad modifications should be minimal (uses Shuttle launch pad).

Military Uses of Space: 1946-1991

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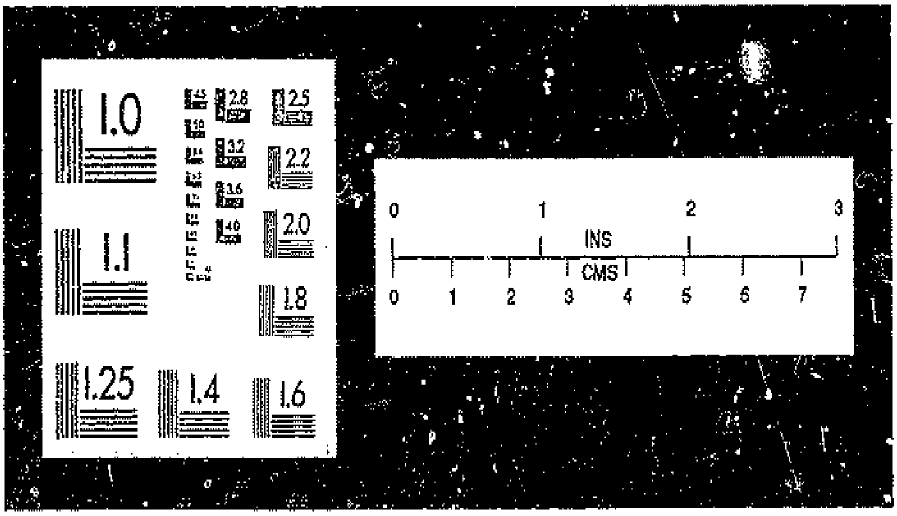

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IV - COST COMPARISON

A. DOD launch scenarios, wherein two commercial ELV launches per year are substituted for two Shuttle launches, are compared. The cost comparisons reflect the Air Force use of either of the two commercial ELVs - the $T34D_7$/Centaur G' or the Atlas II/Centaur G'. Factors considered in these comparisons are:

- Costs incurred through ELV development, production, and launch.
- Cost avoidance accrued from Shuttle flight charge.
- Savings accrued through reduced Shuttle security expenditures.
- Shuttle flight rate effects.
- Effects of dual integraton of selected Air Force payloads.

These cost elements, when applied against the FY86 POM mission model (Figure IV-1), comprise the basis for comparison of the two launch scenarios. The following paragraphs summarize the factors considered in this comparison and the results.

1. <u>ELV Costs</u>

The costs incurred for the commercial ELVs reflect a production rate of four vehicles per year and a launch rate of two vehicles per year (ten vehicles total). The vehicle payment was made in January of the year prior to launch, identical to the Shuttle payment schedule. The cost per flight for the $T34D_7$/Centaur G' and the Atlas II/Centaur G' were \$170 million FY83 dollars and \$207 million respectively.

2. <u>Launch Cost Avoidance</u>

a. Cost avoidance of flying two payloads per year on Commercial ELVs is realized in the year prior to launch. The Shuttle full-cost-recovery cost estimate was derived from the latest NASA available data, POP-83-2. The estimate reflects a Shuttle cost of \$133 million FY83 dollars (\$68.1 million FY75 dollars). The savings from deleted Shuttle flights were based upon these costs and the Air Force mission model presented in Figure IV-1.

TRAFFIC MODEL

YEARLY TRAFFIC 1)	89	90	91	92	93	TOTAL
AFSC						
KSC	6	3-2/3	5-1/3	3-2/3	3-2/3	22-1/3
VAFB	1	1	1	1	1	5
SUBTOTAL	7	4-2/3	6-1/3	4-2/3	4-2/3	27-1/3
DOD OTHER						
KSC	4	2	0	2	2	10
VAFB	2	4	1	3	3	13
SUBTOTAL	6	6	1	5	5	23
NASA						
KSC	5	7-1/3	10-2/3	8-1/3	8-1/3	39-2/3
VAFB	0	0	0	0	0	0
SUBTOTAL	5	7-1/3	10-2/3	8-1/3	8-1/3	39-2/3
COMMERCIAL						
KSC	6	6	6	6	6	30
VAFB	0	0	0	0	0	0
SUBTOTAL	6	6	6	6	6	30
TOTAL	24	24	24	24	24	120

Note: 1) FY 86 POM TRAFFIC (EXTRAPOLATED TO FY 93)

FIGURE IV-1

b. An additional cost savings is realized through the elimination of the optional service charge associated with each Shuttle flight. To date, optional service charges ranging from $1 million to $5 million FY83 dollars per flight have been charged. This cost spread is due to variation in mission and spacecraft flight planning and integration complexity. For this comparison, an average complexity was assumed and a cost of $3 million per flight was used.

3. <u>Shuttle Security Savings</u>

STS security elements which are flight rate dependent were reviewed and estimates made for savings which might be realized by the use of two commercial ELV flights per year. Security related costs for JSC, KSC, and GFSC were determined and allocated into fixed and flight rate dependent catagories on a 40/60 percent ratio, respectively. Similarly, CSOC Shuttle Ops and Planning Complex (SOPC) costs were divided into the same fixed/variable estimates. Based on current cost estimates there is a $50 million FY83 dollar fixed cost per year and a variable cost of $10 million per flight. However, recent discussions with NASA have failed to achieve concurrence with the fixed/variable cost ratio for the NASA elements. NASA maintains that the costs are 100% fixed. Therefore, the savings for deleting two Shuttle flights was assumed to affect only the SOPC variable costs, which resulted in a savings of $6 million per year per flight.

4. <u>Shuttle Flight Rate Effects</u>

Shuttle increased launch costs only occur should the Air Force deleted flights not be resold by NASA. This comparison assumes that the two Air Force deleted flights will be resold-- the most likely scenario. In the unlikely event these flights are not resold, a cost impact could be experienced by the remaining users. These costs are composed of both fixed and variable costs. In order to properly assess the sensitivity of Shuttle flight charge to flight rate, Shuttle flight dependent algorithms were developed. These show a possible flight charge impact of $4 million FY83 dollars (KSC flight) and $2.4 million (VAFB flight) to each remaining user for each flight that is deleted and not resold..

5. <u>Dual Payload Integration</u>

Three Air Force satellite programs, DSP, DSCS and MILSTAR, were selected for dual integration. Costs for dual Shuttle/commercial ELV nonrecurring and recurring integrations were identified. Likewise, any

spacecraft cost impacts created by the requirement for dual integration were identified. The resultant cost impact from the launch vehicle integration viewpoint was identified as a $7 million then year (TY) savings. Similarly, the spacecraft cost impact for dual integration was identified as a $54 million TY cost.

B. Launch Scenario Comparison

Launch scenario comparisons were made where either the $T34D_7$/ Centaur G' or the Atlas II/Centaur G' was substituted for two Shuttle flights per year for a five year period. The $T34D_7$/Centaur G' comparison (Figure IV-2) identifies an Air Force cost savings of $147 million TY dollars for the five year period. The Atlas II/Centaur G' comparison (Figure IV-3) differs from that of the Titan $34D_7$/Centaur G' in that it reflects a cost increase of $288 million TY. This results from the higher cost per flight of the Atlas II compared to the $T34D_7$. As previously noted, because of its high cost and late availability, no launch scenario comparisons were made with the SRB-X for this study. The SRB-X will continue to be examined in expanded concept definition studies currently under contract.

AIR FORCE IMPACTS - T34D7
(FULL COST RECOVERY - MILLIONS OF TY DOLLARS)

FY	85	86	87	88	89	90	91	92	93	TOTAL
2 ORB/YR				-355	-380	-405	-435	-465		-2040
OPT SERV				-8	-9	-9	-10	-11		-47
2 ELV/YR				350	375	395	420	440		+1980
3 PROG DUAL INTEG (LV)	3	5	8	13	9	2				+40
7 SAT REC INTEG (LV)					-3	-9	-13	-14	-8	-47
P/L IMPACT	10	15	13	11	5					+54
SECURITY SAVINGS					-16	-17	-17	-18	-19	-87
STS IMPACT COST	0	0	0	0	0	0	0	0	0	0
TOTAL	+13	+20	+21	+11	-19	-43	-55	-68	-27	-147

ASSUMPTIONS:

ELV DEVELOPMENT AMORTIZED OVER 10 VEHICLES

AIR FORCE FLIES 2 ELVs/YR, NASA RESELLS TWO AIR FORCE DELETED SHUTTLE FLIGHTS

NOTE: MINUS (-) INDICATES SAVINGS

FIGURE IV-2

AIR FORCE IMPACTS - ATLAS II 10 FEBRUARY 1984
(FULL COST RECOVERY - MILLIONS OF TY DOLLARS)

FY	85	86	87	88	89	90	91	92	93	TOTAL
2 ORB/YR				-355	-380	-405	-435	-465		-2040
OPT SERV				-8	-9	-9	-10	-11		-47
2 ELV/YR				420	450	480	515	550		+2415
3 PROG DUAL INTEG (LV)	3	5	8	13	9	2				+40
7 SAT REC INTEG (LV)					-3	-9	-13	-14	-8	-47
P/L IMPACT	10	15	13	11	5					+54
SECURITY SAVINGS					-16	-17	-17	-18	-19	-87
STS COSTS	0	0	0	0	0	0	0	0	0	0
TOTAL	+13	+20	+21	+81	+56	+42	+40	+42	-27	+288

ASSUMPTIONS:
ELV DEVELOPMENT AMORTIZED OVER 10 VEHICLES
AIR FORCE FLIES 2 ELVs/YR, NASA RESELLS TWO AIR FORCE DELETED SHUTTLE FLIGHTS
NOTE: MINUS (-) INDICATES SAVINGS

FIGURE IV-3

V - LAUNCH OPERATIONS

A. Commercial ELV

Launch Complex 41 (LC-41) at Cape Canaveral AFS will be used to launch the upgraded $T34D_7$ or Atlas II Expendable Launch Vehicles (ELVs). The last user of LC-41 was the Titan IIIE Program in 1977. Refurbishment of the complex is required to make it operational. The launch stand will also require modifications to accommodate the chosen vehicle. Launch pad refurbishment and modification costs have been incorporated in this study.

Other facilities for storage and processing the various segments of the ELV will have to be dedicated. LC-36 Centaur processing capability will be used directly or through landline from LC-41.

Both ELV configurations are proposed for on-pad buildup of the launch vehicle with the SRMs and Centaur mated at LC-41. The payload will be encapsulated in the upper portion of the payload fairing and mated last.

With either proposed vehicle system, there is an impact on the launch site. Refurbishment will be required on the Mobile Service Tower (MST) and Umbilical Tower (UT) to provide service and access to the vehicle and payload. Although launch complex studies were made for the Titan during the Manned Orbiting Laboratory Program, early definition of design details will be required. The proposed schedule provides adequate time to accomplish the required facility modifications and, therefore, is considered a low risk.

B. SRB-X

Operation of the SRB-X class vehicles from NASA STS launch facilities at KSC appears to present some problems. Some modifications and additions (such as a payload processing facility) may be needed. If the operation is to be a commercial enterprise, the operators being NASA for the Shuttle and contractor personnel for the SRB-X, there may be some difficulty in reconciling conflicts between the NASA STS use of the facilty and use by the commercial SRB-X interests. The dissimilar launch processing flow for two SRB-Xs, coupled with 22 Shuttle flights per year will have to be reviewed for adequate time line margins to ensure mission capability.

C. Payloads

The identification of candidate payloads concentrated on those spacecraft planning or considering future launches with the STS/Centaur G. Dual integration on STS/Centaur and ELV/Centaur will provide the required flexibility for assured access to space for critical DOD payloads. If integra-

tion can be timed to coincide with an already planned satellite blo^k change, cost impacts can be minimized.

Three USAF spacecraft programs are viable candidates to be launched on the two ELVs per year and to retain compatibility with the STS. These candidates are described in the classified annex to this report.

VI - PROGRAMMATICS

A. Contracting Approach

The commercial ELV program assumes a firm fixed price procurement of ten or more ELVs launched at a rate of two per year with the first launch in early FY89. The contractor is required to finance development, production, and launch services. The DOD contract will be structured to make payment one year prior to launch, with the contractor recovering non-recurring costs spread over the initial quantity of DOD launches. The DOD contract, to be awarded by 1 Oct 84, will stipulate a cancellation liability for all costs up to a predetermined ceiling incurred by the contractor in the event the program is cancelled and the total quantity of DOD launches is not purchased. Considerations for contract length and scope cause alternative fixed price contract types to be considered.

B. Contract Type/Pricing Arrangement

Three alternative pricing arrangements suitable to this procurement are available under fixed price type contracts: Firm-Fixed-Price (FFP); Fixed-Price Incentive, Firm Target (FPIF); and Fixed-Price Incentive, Successive Targets (FPIS). Although from a policy standpoint, FFP contracts are the preferred type, this acquisition leaves some question as to its suitability because of the long period of performance. An FPIS arrangement would provide the Government the option to incentivize the contractor to control costs and reduce the overall costs of the program to the Government. The problem of length of contract remains at the outset and requires an additional negotiation at a later point in time. This approach does, however, mitigate to some degree the problem of length of contract by allowing for adjustment of contract price at a point in time where a greater amount of cost information would be available. The only other mechanism for reducing the inherent risk would be to award a Phase I contract for the initial launches followed by a Phase II contract for the remainder of the program. Any of these approaches can be structured with effective performance incentives.

C. Special Authority

With the following authorities, existing DOD acquisition policy and regulations can accommodate this acquisition.

1. Cancellation liability authority will be required, at the latest, by contract award. The exact approach to seek and obtain Congressional commitment to this arrangement is unclear, however, special

legislation may be required.

2. Allocation of non-recurring cost over the DOD portion of this program does not account for current DOD policy on recoupment of non-recurring cost.

3. Depending on the proposal approach taken by the contractors, cost of capital will be a substantial cost input. Since interest cost is not allowable on a DOD contract, a work-around will be required. At a minimum, a DAR deviation is required to allow interest cost incurred by the contractor.

D. <u>Schedules</u>

1. <u>Commercial ELV</u>

The milestone schedules for the commercial ELV require that with an authority to proceed of 1 October 1984, the contractor will provide a first launch capability on 1 October 1988. A minimum launch rate of two DOD missions per year for DOD missions is required, however, additional commercial launches may be conducted. Both the $T34D_7$ and Atlas II milestone schedules meet these time spans but with varying schedule risks.

The $T34D_7$ development plan identifies a 40-month development and test program providing a potential 8-month contingency. The $T34D_7$ launch operations plan indicates a planned 26 week activity from hardware delivery at the launch site through launch and pad refurbishment.

The Atlas II first article development and delivery schedule shows a 48-month plan to achieve the 1 October 1988 launch capability. Two critical program paths determine the 1 October 1988 launch availability. One is the delivery of the liquid rocket engines. The second is the design, manufacture and test of the thrust structure.

2. <u>SRB-X</u>

The NASA study estimates that the SRB-X concept could be developed within 54 months from ATP to first flight. This does not include time for trade studies, concept selection and competitive selection of a development contractor. This activity would add at least an additional 24 months to the schedule. Necessary facilities modifications could be accomplished within this same time period. A concern here would be the non-interference with ongoing STS operations while the facilities changes are in work.

VII - CONCLUSIONS

The DOD Space Policy, as approved by the SecDef and provided to the President, defines a need for the DOD to maintain a complementary launch system to the Shuttle to provide "high confidence of access to space." This report presents alternatives to provide the required complementary launch capability while maintaining DOD's overall commitment to the Space Shuttle. These alternatives are the $T34D_7$/Centaur G', the Atlas II/Centaur G', and the SRB-X.

The technical analyses indicate that any one of the three vehicles can provide the required Shuttle equivalent performance of 10,000 pounds to geosynchronous orbit and the payload volume of 15 feet diameter and 40 feet length. All three vehicles require development work. The $T34D_7$ and the Atlas II are modifications to the existing T34D and Atlas G launch vehicles. The Centaur G' is an adaptation of the Shuttle Centaur. The SRB-X is developed from Shuttle Solid Rocket Boosters, the T34D Stage II, and the Centaur.

The costs for the commercial ELVs ($T34D_7$/Centaur G' and Atlas II/ Centaur G') have been reviewed and found to be properly scoped. The costs are of such a magnitude that the vehicles appear to be viable candidates to complement specified Shuttle flights. To make commercial ELVs commercially viable, a 10 vehicle buy to be flown at a two per year rate is required of DOD with the development cost prorated over the 10 vehicles. The vehicles would be paid for by the DOD under the same arrangements as for a Shuttle flight, i.e., one year before launch. The cost per flight and initial launch capability of an SRB-X under the same groundrules are such that it does not presently appear to be a viable candidate.

The probability of impact to the Space Shuttle flight rate by the introduction of two ELVs per year appears small. In light of the large volume of traffic contemplated by NASA (up to 40 missions per year), the President's message on the vast potential for commercialization of space, and the added flights required for the recently directed Space Station, NASA's 24 flight per year Shuttle flight capability will probably fall far short of the demand. The resale of two DOD Shuttle flights per year in such an environment appears to be a virtual certainty. Thus, in addition to the immeasurable benefits of providing a complementary system for assured access to space, the effect of two ELVs per year for DOD payloads could be to save DOD launch

costs, lower NASA capital expenditures for additional launch facilities, and not impact the remaining Government, commercial, and foreign users.

The desired need date for the commercial ELV would be a first flight in early FY89 which dictates a contract start date in early FY85 for the commercial ELVs. A preliminary schedule assessment indicates that the $T34D_7$/Centaur and Atlas II/Centaur can meet the schedule while the SRB-X cannot.

Efforts should continue to refine the concept, receive firm costs, and proceed with procurement of the commercial ELV to provide a first launch in early FY89. This vehicle will provide a complement to the Space Shuttle, thus assuring the Nation's access to space.

APPENDIX

I. BOOSTER DESCRIPTION

A. Requirements

The upgraded Expendable Launch Vehicle (ELV) performance capabilities will be determined on the basis of launch from Eastern Space and Missile Center (ESMC). The vehicle must be able to deliver a 10,000 pound spacecraft to geosynchronous orbit (GEO). The vehicle must also have the capability to vary the inclination of this orbit up to 65 degrees. In addition the vehicle must deliver a spacecraft weighing 11,500 pounds to an elliptical orbit which has a period of 12 hours, is inclined at 63.4 degrees and has an argument of perigee of 270 degrees. Upgraded ELVS must accommodate a spacecraft envelope defined as a cylinder 40 feet long and 15 feet in diameter. Some truncation on the forward location of the spacecraft may be permissible on a program peculiar basis.

B. Configurations

1. Centaur Upper Stage

In October 1982 the Air Force and NASA reached agreement on the principles for design, development and procurement of a common Centaur G upper stage. This upper stage is being developed in two unique versions for use with the Shuttle. The first version to be deployed is the NASA-unique configuration, designated Centaur G'. This version becomes operational in 1986 for the Galileo and Solar launches. The Air Force version of this upper stage is designated Centaur G and trails the G' development by a few months. Both ELV configurations would use the Centaur G' vehicle as the baseline upper stage. For operational compatibility, the forward interface of the G' vehicle would have to be modified to accommodate the DOD payloads. Satellite mechanical attach points and electrical interfaces will be duplicated for the ELV/Centaur. Additionally, there will be unique design modifications required to eliminate some of the Shuttle-peculiar equipment such as attachment outriggers, propellant dump system, dual failure tolerant arm/safe sequence, and vents and to also adapt the Centaur G' to each of the expendable vehicles. Figure AI-1 depicts the Centaur G' and the general changes required to adapt it to the Atlas II vehicle; however, some of these changes, such as addition of a range safety system, would also be applicable to Titan and SRB-X. At this time, it appears that there are no major development obstacles to readily integrating the Centaur G' vehicle as it is being developed to an expendable launch vehicle.

2. Titan $34D_7$

a. System Description

The improved Titan 34D with seven segment solid rocket motors and stretched Stages I and II is an upgraded expendable space launch vehicle that will provide the Government with increased performance capability over that presently available in any expendable vehicle configuration.

Modified Centaur G-Prime Vehicle

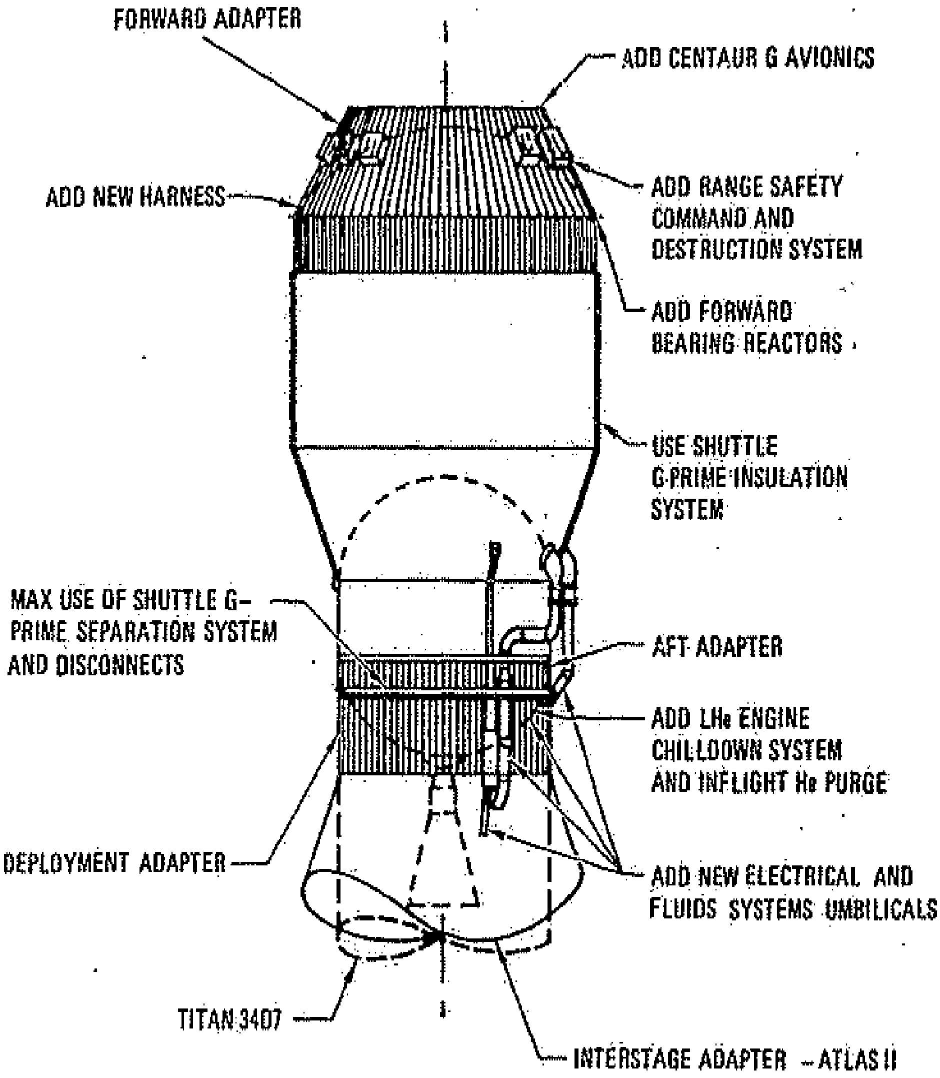


FIGURE AI-1

The improved Titan 34D vehicle as presented in Figure AI-2 draws heavily from its predecessor Titans. The solid rocket motors (SRMs) are the same as used on current Titan programs except they are lengthened from 5-1/2 segments to seven segments. Stages I and II are the same, including engines, as used on current Titan programs except the fuel and oxidizer tanks in both stages are lengthened. The interstage adapter between Stages I and II is strengthened to accommodate the stretched vehicle.

Software currently used on the Titan 34D Transtage program will be used to the maximum extent practical. Minor changes will be necessary to accommodate vehicle checkout and launch requirements.

The Stage II will mate with the Centaur and the payload fairing through an interstage adapter (ISA) similar to that used for the highly successful Titan IIIE/Centaur program that flew NASA interplanetary missions during the 1970s.

The payload fairing will be a new design fairing. However, the fairing is not without precedence since a similar bulbous type fairing (14 feet diameter) was launched very successfully on the Titan IIIE/Centaur program.

b. Sub-Systems

1) Solid Rocket Motors (SRMS). Two seven-segment solid rocket motors (SRMs) form Stage "0" of the improved Titan 34D vehicle. Stage "0" consists of the propulsion (motor case with internal insulation, solid propellant and nozzle), structure, ordnance, thrust vector control (TVC), flight instrumentation and electrical systems.

The seven segment SRM was originally developed by the Air Force for the TIII Manned Orbiting Laboratory program. The major difference between a seven segment solid booster and a 5-1/2 segment solid booster on the current Titan 34D configuration, is that in addition to the added segments, the forward closure skirt is 40 inches longer, the three aft segments will have slightly thicker insulation, the aft closure insulation contour will be modified, the throat will have a larger throat diameter with a larger expansion ratio and the exit cone extension is larger. The aft skirt will be a welded structure due to the lead time for forging. The seven segment SRM ballistic performance (total impulse) increases 30% from the Titan 34D SRM configuration with a burnout weight increase of 13,860 pounds for each SRM.

2) Liquid Rocket Engines (LRE). The Stage I propulsion system has two engines that provide pitch, yaw and roll control. Stage II has one engine that provides pitch and yaw control. Stage II roll control is provided by ducting turbine exhaust gases through a swiveled roll control nozzle. Each engine has a regeneratively-cooled thrust chamber, gas generator, start cartridges, connecting plumbing, electrical and instrumentation wiring harnesses, pressure components, turbine pumps, and an ablative nozzle extension.

Titan 34D7/Centaur

- 7 SEGMENT SRM's
- STRETCHED STAGE I AND II
- 200 IN PAYLOAD FAIRING
- CENTAUR G' UPPERSTAGE

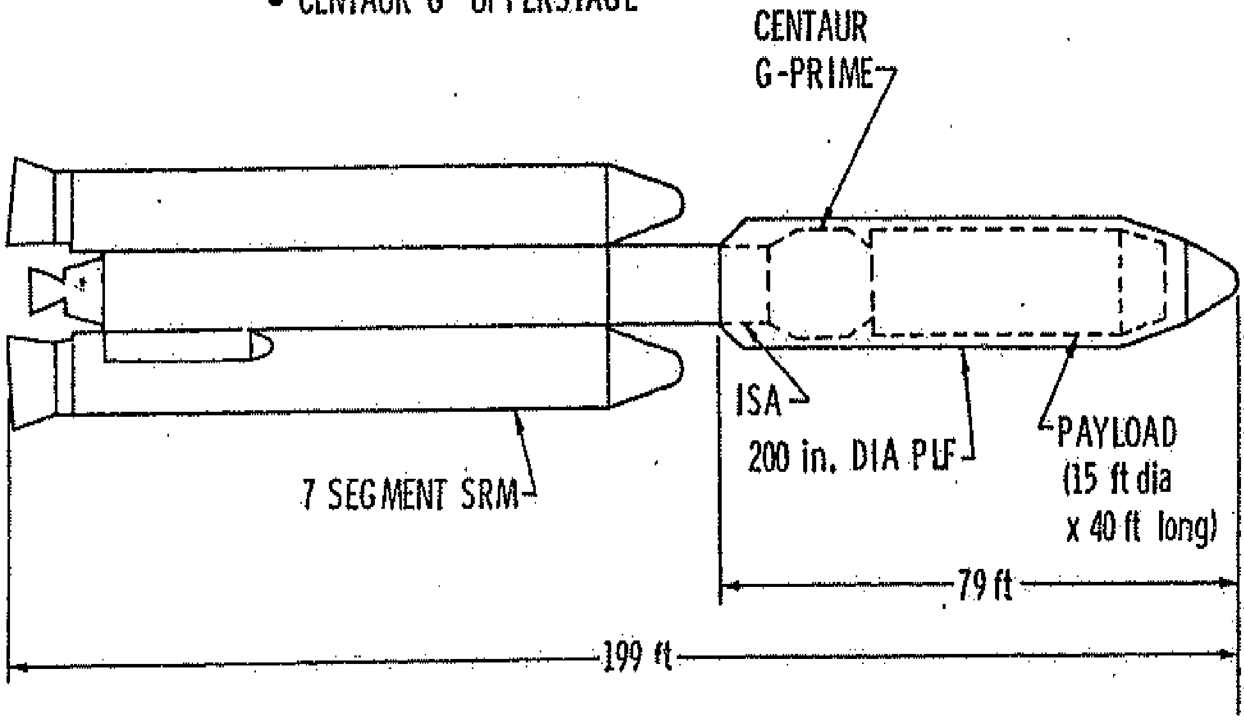


FIGURE AI-2

3. Core Vehicle

a. Stages I and II

Both the oxidizer and fuel tank in each core stage will be lengthened in comparison to the current Titan 34D core vehicle configuration. Stage I will be lengthened approximately 83 inches overall and Stage II approximately 42 inches overall. This type of design change has a proven highly reliable history on the Titan Program.

Both core stages use storable liquid hypergolic propellants that can remain aboard in a launch-ready state for extended periods. The fuel, Aerozine 50 (A50), is a blend of 50% hydrazine and 50% unsymmetrical dimethylhydrazine (UDMH). Nitrogen tetroxide is the oxidizer. The liquid rocket engines are hydraulically gimballed and fed by turbine pumps. The propellant tanks are pressurized on the ground with dry nitrogen. An autogenous pressurization system using cooled fuel-rich turbine exhaust gas for the fuel tank and vaporized nitrogen tetroxide for the oxidizer tank maintains the in-flight pressure requirements.

b. Guidance

The improved Titan 34D vehicle avionics system will use the same components currently being used in the Titan Transtage for the Titan portion of flight. Minor changes to the guidance and control software will be required. The components will be supported on modified Transtage trusses located between Stage II and Centaur.

c. Data System

This system will provide the capability of collecting measurement data on the vehicle during checkout, launch and flight. The data stream will be provided to an RF subsystem for transmission and by landline to the ground equipment. The data system will consist of: remote multiplexed instrumentation subsystem (converter unit and remote multiplexer units), reference power supply, voltage distribution units, signal conditioners, end instruments, interconnecting cabling, address and data bus connectors, and an RF subsystem (S-Band transmitter, coaxial cabling and broadbeam antenna).

d. Flight Safety System

The flight safety system (FSS) consists of two systems--the command shutdown and destruct system (CSDS), and the inadvertent separation destruct system (ISDS).

Either system has the capability to destroy that portion of the vehicle to which it is electrically connected. The CSDS has the additional capability of shutting down Titan core engines without destruction. The CSDS responds to commands transmitted from the ground and while the ISDS is activated and certain electrical paths are interrupted as a result of inadvertent separation of stages in flight. The command shutdown and destruct

system will consist of two command receivers, a multiport junction, two antennas, coaxial cabling and interconnections with the ordnance subsystem.

e. Power Subsystem

The power systems for transient power and for the flight safety system will be basically the same as the systems currently in use on the Titan 34D/IUS vehicle. The power system for accessory (general) power, guidance power and instrumentation power will be basically the same as currently used on the Titan 34D/Transtage vehicle. Trusses, cabling and component mounting will be modified or redesigned to accommodate an inertial system on Stage II of a Titan 34D vehicle. The umbilical configuration will be like that used for Titan 34D/IUS, and all batteries will be of a silver zinc type and of designs currently in use.

f. Payload Fairing

A comprehensive study and a detailed preliminary design of a 200-inch diameter improved Titan 34D payload fairing (Fig AI-3) was completed in early 1981. The study included preparation of layouts to define configuration requirements, and preparation of analyses to verify conformance to strength, thermal, acoustics, mass properties, and cleanliness requirements. Testing was accomplished to verify the separation joint to be satisfactory for the 200-inch diameter configuration. Trade studies were completed, basic interface requirements were established, ground support equipment needs were established, and a factory to launch site handling flow plan was established.

The design approach for the improved Titan 34D/200-inch diameter payload fairing is to use the same design concepts as those used on the Titan 34D/IUS payload fairing. The structural shell will be of isogrid construction and can be machined using the same facilities used to fabricate the Titan 34D/IUS isogrid payload fairing hardware. The payload fairing will enshroud the Centaur upper stage and provide a 15 ft dia X 40 ft length spacecraft envelope equivalent to the Shuttle/Centaur G.

It is anticipated that a circumferential field joint will be required at the general region of the upper end of the encapsulated Centaur stage. This field joint will be similar to the field joint at the upper end of the IUS on the Titan 34D/IUS isogrid payload fairing. The base cylindrical section and the forward cylindrical section will each consist of six isogrid skin sections of appropriate length. Access doors, as required for spacecraft and Centaur servicing, will be similar to the Titan 34D/IUS isogrid access doors. These doors are designed as load carrying access doors and are configured to fit the isogrid pattern.

Fairing Inboard Profile

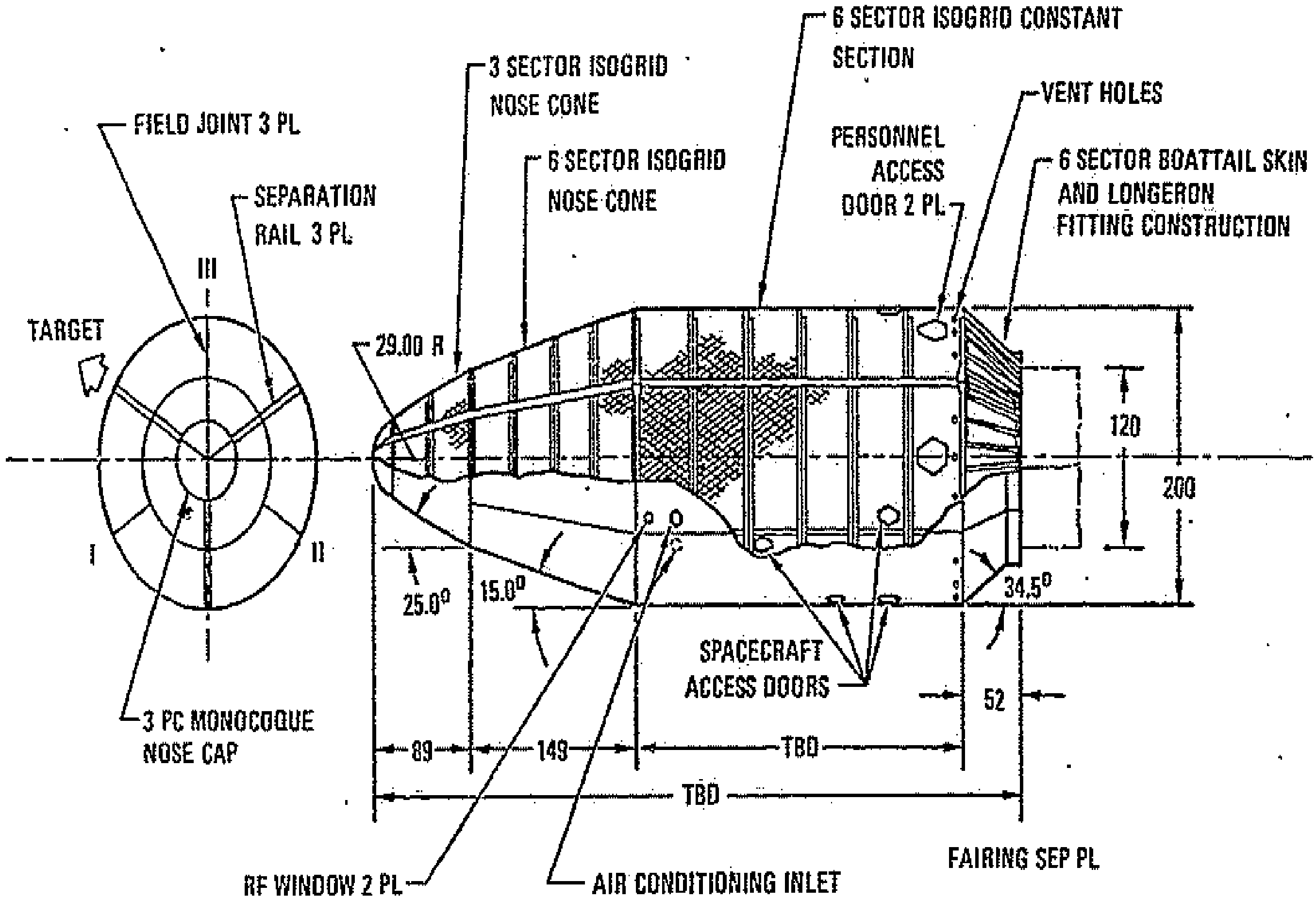


FIGURE AI-3

APPENDIX

3. Atlas II/Centaur Configuration

a. System Description

The commercial Atlas II/Centaur being proposed to Space Division is a 180 foot long x 200 inch constant diameter vehicle as illustrated in Figures AI-4 and AI-5. This diameter was selected because the payload fairing must envelope 15 foot diameter payloads. This constant diameter minimizes aerodynamic stability and vehicle buffeting loads effects.

The baseline propulsion system will consist of five liquid engines, four solid rocket motors, and two roll control modules. Except for the roll control modules, all engines will be ignited at T-0. The four solid rocket motors will be jettisoned at T+100 seconds. At booster stage cutoff, the four liquid propellant engines will be shut down and jettisoned as part of the booster thrust structure, and the two roll control modules will be activated to provide roll control during the remaining sustainer flight phase. This is similar to the present Atlas, except it has only two booster and one sustainer engines, no solids, and two vernier engines for roll control.

Atlas II / Centaur G-Prime

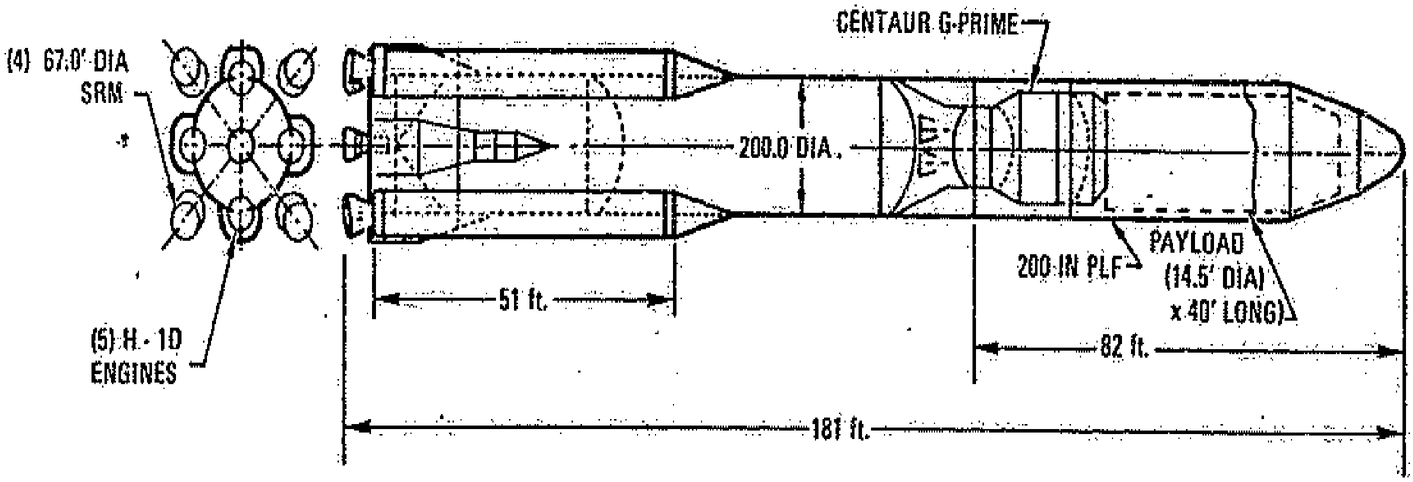


FIGURE AI-4

Comparison – Atlas G vs Atlas II

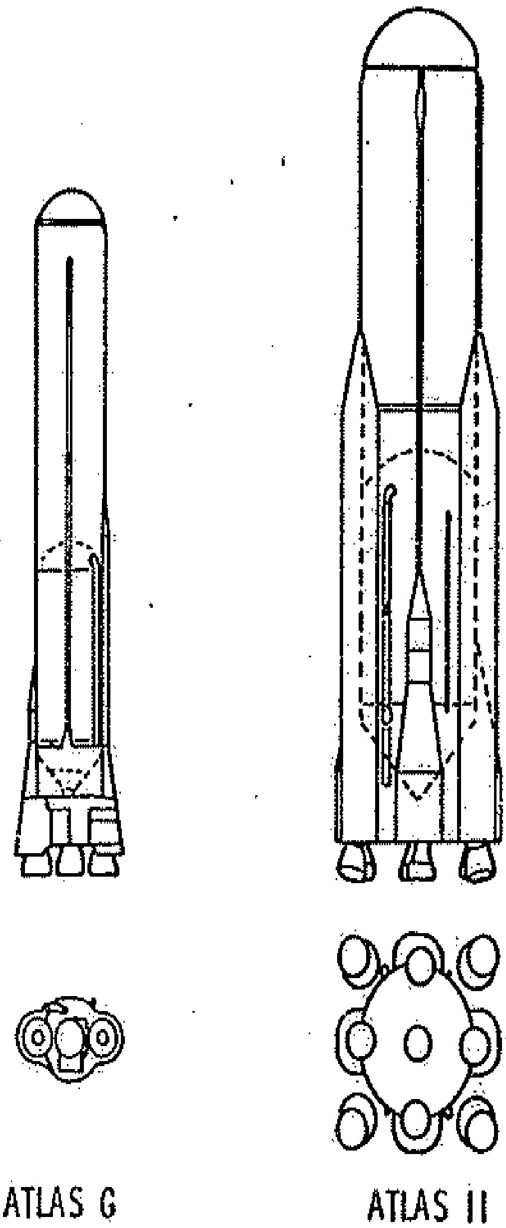


FIGURE AI-5

The baseline Atlas II pneumatic system consists of the propellant tank pressurization system, a liquid oxygen boil-off valve, the propellant tank intermediate bulkhead differential pressure system, and the propellant tank programmed pressure/booster separation system. The concept is similar to the Atlas vehicle configuration, with the primary difference being one of sizing for the larger tanks.

There are minimal changes planned to the current Atlas avionics hardware. The most extensive change will be any redesign required to requalify the avionics packages to the higher environments which result from the added thrust of the five liquid engines and four SRMs during the boost phase of flight.

There will be minor modifications to the electrical system harnesses due to the additional retrorocket relay box and the new propellant utilization system, but the existing battery capacity is adequate for the Atlas II application.

To accommodate the additional requirements of the Atlas II, there will be modifications required to the Sequence Control Unit (SCU) to provide additional discretes, and to the Servo Inverter Unit (SIU) to provide the gimbal control servos for the five liquid engines. No design change is anticipated to the basic Centaur inertial reference unit and digital computer, which are used for guidance and control of the entire Atlas II Centaur vehicle. In order to satisfy range safety requirements, the basic Atlas Centaur tracking and flight termination systems must be added to a Shuttle Centaur stage when flown on an Atlas II.

b. <u>Sub-Systems</u>

1) <u>Solid Rocket Motors (SRMs)</u>

The SRMs proposed are 5.6 feet in diameter by 51 feet long and produce 7.5×10^6 lb-sec total impulse. The SRMs will be made in two longitudinal segments to facilitate handling and installation.

Two SRM designs are under consideration. One is a derivation of the Castor IV HLX flown on the Thor vehicle and manufactured by Thiokol Chemical Corp. The other is based on the Algol IIIB flown on the Scout vehicle and manufactured by Chemical Systems Division, United Technologies. In either case, modifications are required to meet Atlas II requirements. The contractors have chosen relatively low cost, proven construction materials which should minimize problems during development.

APPENDIX

2) Liquid Rocket Engines (LREs)

The current Atlas launch vehicle uses the Rocketdyne MA-3 and MA-5 liquid rocket engines--two boosters and one sustainer. These engines are similar to the H-1D and the RS-27 engines flown on the Saturn 1B and Thor Delta vehicles respectively, and proposed for the Atlas II. Many components are common to the three configurations and have a long flight history. The H-1D and the RS-27 have nearly identical performance and employ the same turbopump and thrust chamber assemblies, although the packaging is different on the H-1D. The turbopump is gimbaled with the thrust chamber, whereas on the RS-27, only the thrust chamber is gimbaled and the turbopump is attached to the structure. Atlas II has four booster engines and one sustainer engine of approximately 205,000 lbs sea level thrust each.

The third engine configuration considered is an engine manufactured by Aerojet and is an adaptation of the engine currently used on the Titan III Stage I, modified to use the Atlas propellants, RP-1 and LOX. Thrust of the engine is approximately 223,000 lbs at sea level. The installation of the four boosters and one sustainer would be similar to the RS-27 in that it also utilizes only chamber gimbaling.

Figure AI-6 compares the three candidate engines.

Any of the LREs will require modifications for extended burn times of the sustainer engines (about 375 sec.) and minor changes in the hydraulic system.

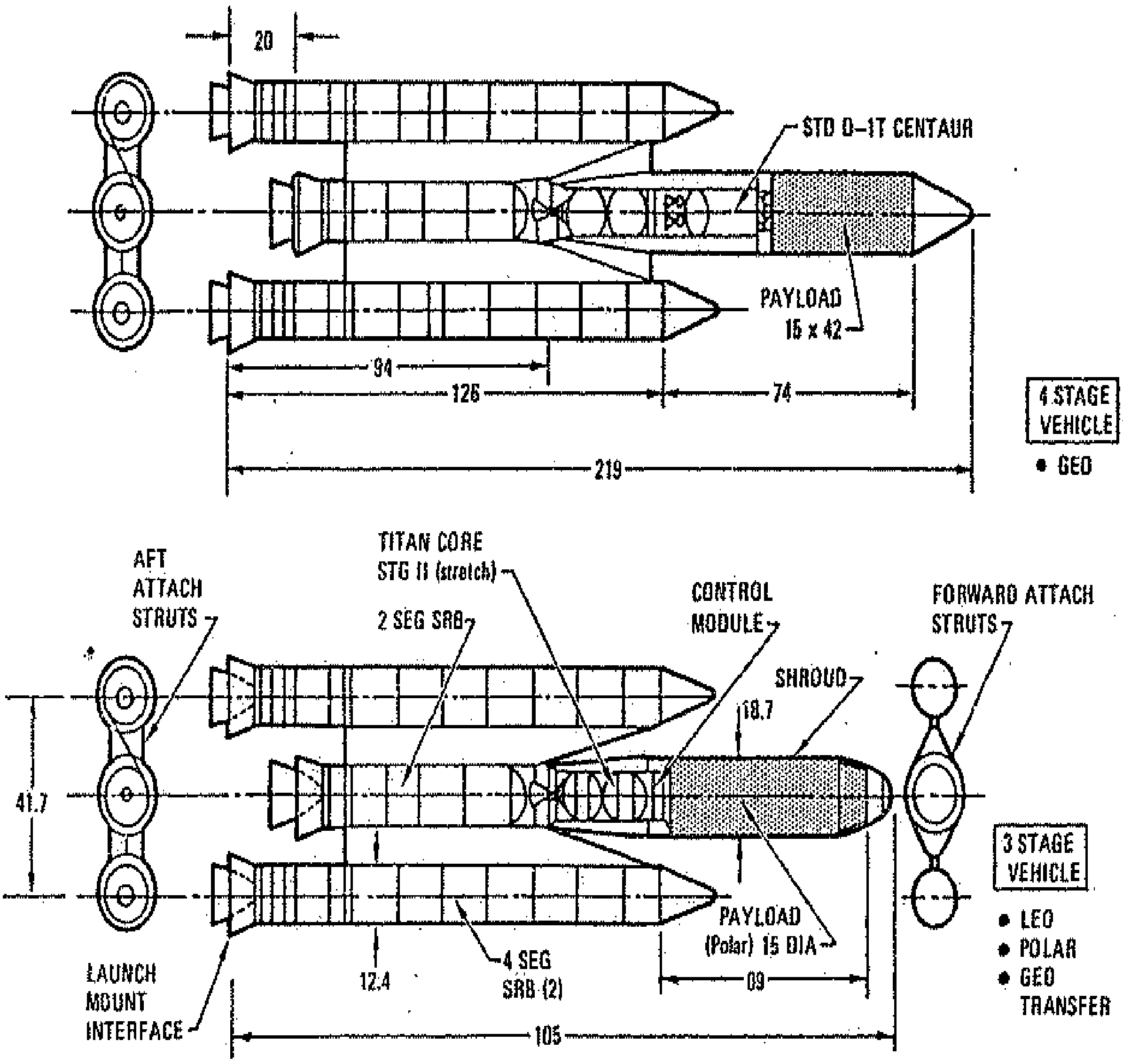
3) Core

The Atlas II booster thrust structure (Figure AI-7) is similar to the current Atlas system. The basic difference is its 200 inch diameter. The thrust structure absorbs the thrust loads from five liquid rocket engines and four solid rocket motors.

As with the existing Atlas, the thrust barrel acts as a support platform for the entire vehicle and provides aerodynamic and thermal protection for the booster engines and internal equipment. The barrel is attached to the fuel tank ring with separation latches and will be guided on jettison rails when the latches are released for booster staging.

Three liquid engine candidates have been investigated: Rocketdyne H1-D, Rocketdyne RS-27, and Aerojet engines. The thrust structure required for each LRE system is similar, but because of the engine candidates' differing locations and sizes, the requirement for nacelles range in size from very large for the H1-D engines, to none at all for the Aerojet arrangement requirement. However, the Aerojet system will require external pods to house pressurization bottles because there is not sufficient room to mount them inside the thrust barrel.

SRB-X Vehicle General Arrangement



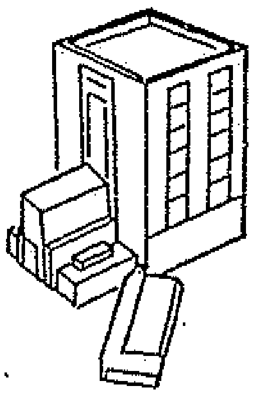
NOTES:
- FIRST 3 STAGES IDENTICAL
- ALL DIMENSIONS IN FEET

FIGURE AI-8

Facility Modifications

- ONLY ITEMS PECULIAR TO SRB-X – NOT TO SUPPORT FLIGHT RATES GREATER THAN STS CAPABILITY

VAB



- USE HB-4
- RELOCATE ET C/O CELL
- NEW ACCESS PLATFORMS
- CRAWLERWAY EXTENSION

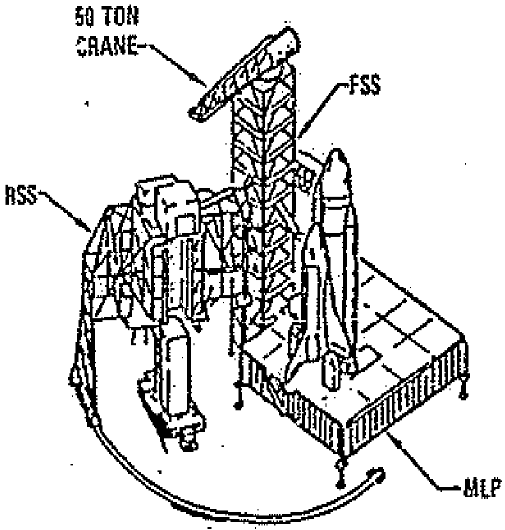
LAUNCH PROCESSING SYSTEM (LPS)

- FOR STG 2, 3, 4 AT PAD AND FIRING RM

SRB PROCESSING AND STORAGE FACIL (PSF)

- BUILD UP STANDS–STG 2
- STORAGE–STG 2

PAD 39B



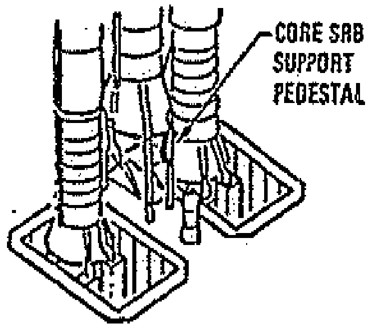
FIXED SERVICE STRUCTURE (FSS)

- REPLACE HHC WITH 50 TON CRANE
- BEEF UP FSS
- REWORK LIGHTING MAST
- ADD CRYO STAGE SERVICING AND T-0 UMBILICAL
- ADD PAYLOAD SERVICING AND T-0 UMBILICAL

ROTATING SERVICE STRUCT (RSS)

- ADD PAYLOAD ACCESS ARM
- ADD HYPERGOL UMBIL (STG 3)

MLP



MLP (modify-1, -2, or -3)

- BEEF UP COMPT 38
- T-0 UMBILICAL
- PEDESTAL FOR CORE

OPTIONAL

- NEW MLP IF >23 FLTS/YR AT KSC

FIGURE AI-9

APPENDIX

The second stage is not recoverable and consists of two of the standard SRB segments. A new grain design and nozzle geometry are required to achieve the needed acceleration and thrust profile. Roll control during second stage burn is provided by thrusters mounted in the forward skirt.

Stage three is a modified Titan Stage II. Principal modifications include increasing the propellant loading by 50% to a total of 101,000 lbs and converting to a columbium engine skirt to accommodate the longer burn time. The new engine skirt also has a larger expansion ratio giving a 3-sec improvement in specific impulse. Engine thrust level is 100,000 lbs.

The payload shroud is 200 inches in diameter and was sized to accommodate a 15 foot diameter payload with length sufficient for a standard Centaur D-1T plus 40 foot long payload. Thermal considerations dictated design features of the nose cone. The fourth stage is basically a Centaur with some structural modifications to accommodate this application. Separation, as well as shipment of the large structure, dictated a shroud design with three longitudinal sections, each divided into lengths to cover a wide range of payloads (Figure AI-10).

C. PERFORMANCE

1. Titan $34D_7$ Performance

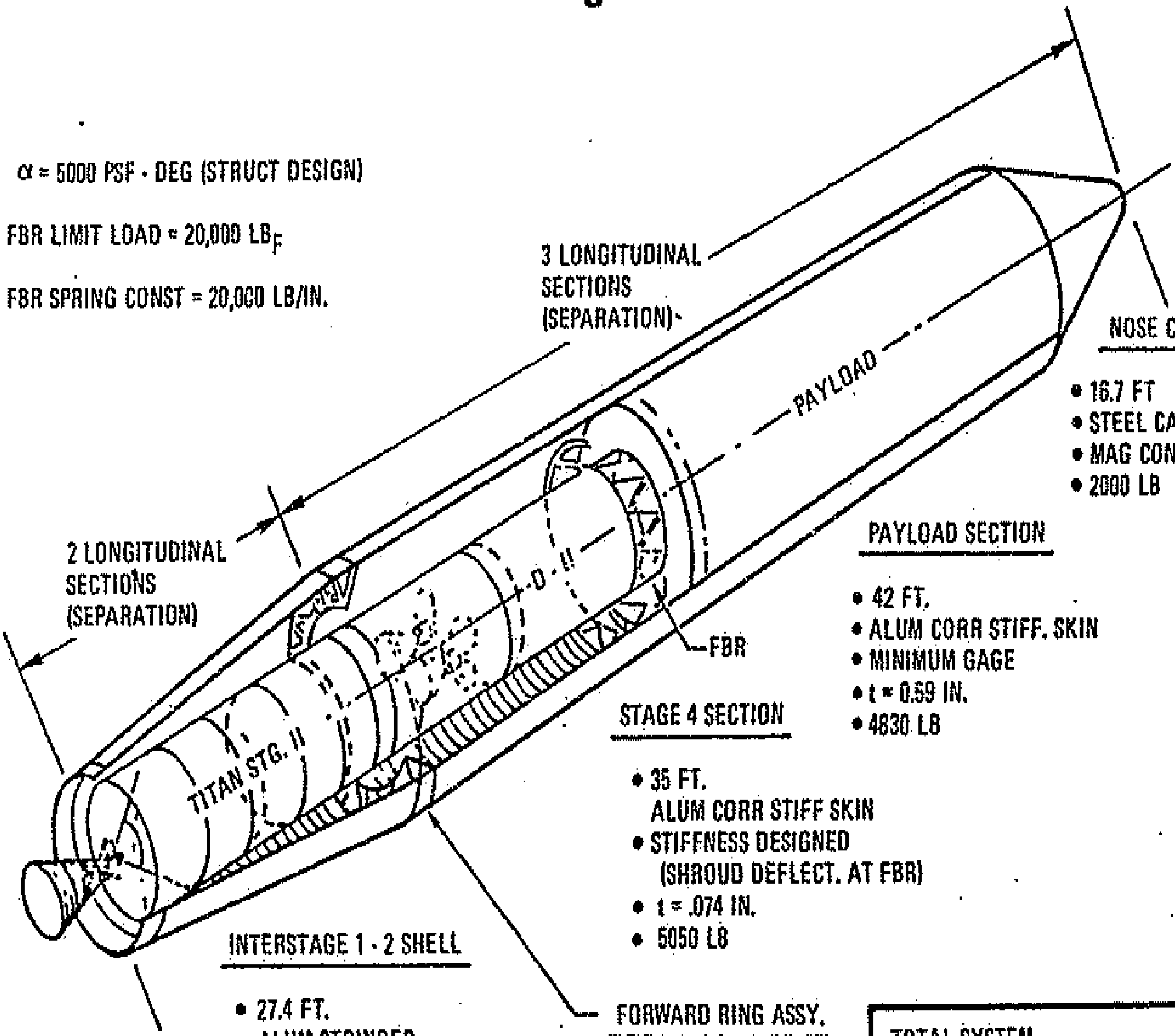
The Titan launch vehicle configuration was driven by the energy requirements of the geosynchronous mission, which has the highest requirement of the missions defined. The trajectory shaping and optimization techniques for this mission are well understood because of the many years of experience in flying such missions in the Titan III and 34D programs.

Detailed trajectory simulations for the geosynchronous mission and the 12 hour elliptical orbit mission were made. These simulations demonstrate that the proposed $T34D_7$ configuration will deliver a spacecraft weight of 10,200 lbs to the geosynchronous orbit and in excess of 15,000 lbs to the 12 hour elliptical orbit (structural capability is limited to 11,500 lbs) with the Centaur G' upperstage.

Missions with inclination requirements of from 0 to 35 degrees can be accommodated by launching within the currently approved flight safety corridor for Titan 34D. Higher inclination missions will require launching the vehicle on a northerly azimuth such as the 35 degree azimuth which has been approved for Shuttle (STS) launches. This azimuth was used for the simulation of the 12 hour elliptical orbit mission.

Shroud Design Features

- α = 5000 PSF · DEG (STRUCT DESIGN)
- FBR LIMIT LOAD = 20,000 LB_F
- FBR SPRING CONST = 20,000 LB/IN.



NOSE CONE
- 16.7 FT
- STEEL CAP
- MAG CONIC
- 2000 LB

PAYLOAD SECTION
- 42 FT.
- ALUM CORR STIFF. SKIN
- MINIMUM GAGE
- t = 0.59 IN.
- 4830 LB

STAGE 4 SECTION
- 35 FT. ALUM CORR STIFF SKIN
- STIFFNESS DESIGNED (SHROUD DEFLECT. AT FBR)
- t = .074 IN.
- 5050 LB

INTERSTAGE 1 - 2 SHELL
- 27.4 FT.
- ALUM STRINGER STIFFENED SKIN, t = .170
- STIFFNESS DESIGNED (SHROUD DEFLECT. AT FBR, VEH. LOWER MODE FREQ. IN BENDING)
- 5560 LB.

FORWARD RING ASSY.
- 1.3 FT.
- ALUM TRUSS
- 2320 LBS

TOTAL SYSTEM (INCLUDING INTERSTG 1 - 2 SHELL)
LENGTH = 122.4 FT MAX DIA. = 18.7 FT WEIGHT = 19,700 LBS

FIGURE AI-10

APPENDIX

2. Atlas II/Centaur Performance

The proposed configuration is a growth version of the Atlas/ Centaur vehicle which has been studied by GDC over the past several years. While the configuration represents a conceptual design, the concept utilizes flight proven hardware. In order to size the vehicle, a baseline reference trajectory simulation was developed to provide the design 11,000 lbs (including 1,000 lb margin) payload system weight.

The quoted performance capability is based on an assumed set of trajectory design ground rules and constraints as well as mass property estimates for hardware which is yet to be built. While these assumptions and estimates appear to be reasonable, they will be more precisely defined as the contractor study proceeds.

It should be recognized that the configuration and data presented above represent a baseline for preliminary design and study purposes, and are not intended to exactly represent the final design. From a performance standpoint, there appears to be minimal technical risk for the selected configuration; that is, except for some variations in weights, the hardware is expected to perform essentially as predicted. Any performance risks are associated with the present uncertainties in the trajectory ground rules and constraints. Any changes from the assumed baselines can be easily handled by a slight adjustment to the SRM sizing.

3. SRB-X Performance

The SRB-X performance is based on data and analysis contained in an exploratory concept study. The system configuration is very preliminary and the performance is based on an exploratory concept with estimate weights and performance constraints. These data were reviewed for the commercial ELV requirement. The geosynchronous performance for the four stage SRB-X/Centaur vehicle from KSC is approximately 12,000 lbs. Gross lift-off weight is approximately 3.4 million lbs.

D. VEHICLE GROWTH POTENTIAL

1. Titan 34D$_7$ Growth Potential

Although this vehicle configuration is approaching the limit of its current design concept, there still remain improvements that could be made to increase performance. Such improvements include:

a. Modification of the solid rocket motor nozzle control system.

b. A change in the aft skirt and heatshield on the solid motors.

c. Update of the thrust level of the Stage I and II liquid rocket engines.

d. Provision for an extendible nozzle on the Stage II liquid rocket engine.

Accomplishing all of the improvements stated could result in a payload capability increase of 600 to 700 lbs for the geosynchronous mission.

In addition, the vehicle contractor has performed studies of a large diameter core vehicle using either two, four, or six solid rocket motors. Such vehicles have significantly improved performance capabilities utilizing significant amounts of Titan technology.

2. Titan Trade Studies

Confidence in the performance capability stated above is a result of several studies conducted over the past three years. These include the Mixed Fleet Study conducted at Aerospace in 1981, the Titan 34D Performance Improvement Study conducted by MMA and supported by Titan vehicle contractors in 1982, and a Titan/Centaur study conducted in 1983. Pertinent trade studies relating to performance involved solid rocket motor sizes, Stage I and Stage II extended tankage, upper stage vehicle size and capabilities, and payload fairing length requirements. The relationship of these areas to structural design dynamics, control capability, ascent flight environmental constraints, launch facility modifications, etc., were studied and resulted in the proposed configuration.

3. Atlas II Growth Potential

The primary growth potential for the Atlas/Centaur G' is centered around Centaur improvements. As used in the study, the Centaur vehicle represents a minimum modification to the Centaur G' configuration designed for use in the STS orbiter bay. Considerable weight savings (or additional payload capability) could be gained by removing all hardware not required on the expendable launch vehicle (such as the propellant dump system). A performance increase as great as 800 lbs may be available. In order to maintain commonality with the STS/Centaur G' vehicle, these changes were not considered

in the design baseline. It was assumed that only those changes required to support the DOD payloads would be made.

4. SRB-X Growth Potential

The concept exploration studies for the SRB-X explored a range of performance capabilities. Due to the preliminary nature of these studies vehicle growth potential in the context of the commercial ELV has limited meaning.

E. ANALYSIS

1. Structural Loads and Dynamics

a. Titan Structural Loads and Dynamics

The structural loads on the improved Titan 34D vehicle will be larger than those observed on the present Titan 34D configuration. The increased loads are due to:

- Payload fairing diameter and length increases, and
- Stretch of the Stage I and II booster core.

The increased loads will be compensated for in the stretched core design. Core stringer size and tank thickness will be modified to accommodate the increased loads. The same design changes will be employed as used on previous Titan launch vehicle improvements. The anticipated design change is considered normal engineering.

A feasibility study was conducted in 1980 for a T34D/Centaur vehicle which included the use of an 83 foot long x 14 foot diameter payload fairing. The airload placard study results showed an increase in core strength is required for 14 foot diameter payload fairings for lengths exceeding 70 feet.

2. Stability Guidance and Controls

a. Titan $34D_7$

A major concern encountered in designing the flight control system (FCS) for a launch vehicle with a long, bulbous payload fairing is to provide adequate vehicle stability during the aerodynamic portion of flight and concurrently to provide a means of alleviating the aerodynamic loads on the vehicle.

A Martin Marietta feasibility study conducted on Titan 34D, the current Air Force launch vehicle, was completed in late 1979. This configuration utilized the Titan 34D launch vehicle with a Centaur D1-T and the Centaur Standard Shroud (CSS) extended 25 feet (total payload = 14 feet x 83.5 feet). The Titan IIID type analog FCC configuration was used, with LASS, in conjunction with the developed ADDJUST program to minimize aerodynamic loads. Adequate nominal vehicle stability was shown for this long, large diameter payload fairing configuration, as well as determining the required core beef-ups.

Another Martin Marietta feasibility study using the Titan 34D booster vehicle used the upper stage Transtage control module, including the Transtage digital FCS, and a 16.7 foot diameter x 53.25 foot length payload fairing. Because of the large diameter payload fairing, the LASS/ADDJUST combination for load alleviation was baselined. Initial stability assessments during the study indicated that current Titan 34D stability margin objectives could be met.

Additional stability assessments have been made for several Titan growth configurations including stretched core stages, seven segment SRMs, and various upper body/payload fairing configurations. Although this improved Titan 34D configuration has not been specifically assessed, the Titan Improvement Study considered both the Titan 34D and the improved Titan 34D, both with an IUS upper stage and a 16.7 foot x 68 foot payload fairing. The initial assessment of this improved vehicle configuration is that an adequate margin for flight stability will be achieved.

The inertial guidance system is the same system as used on Titan 34D. It will be used from lift off through Stage II separation. The proposed software system for consideration is the Magic 352 with basic guidance and flight control functions that are used for Titan 34D/Transtage.

b. Atlas II

A stability analysis for the Atlas II/Centaur with a worst case (i.e., longest) payload fairing length is to be conducted under the concept definition study to assess any control problems associated with this configuration.

3. Propulsion Upgrades

a. Titan $34D_7$ Solid Rocket Motors

Higher Solids Loaded PBAN Propellant

The higher solids loaded PBAN propellant provides performance improvement by increasing propellant density and specific impulse. This potential growth is considered to be a low to moderate risk option.

Thrust Level Optimization.

The optimum thrust profile could be optimized without exceeding any vehicle constraints by modifying the propellant burn rate and/or propellant grain. This is considered a low risk performance improvement.

b. Atlas II Solid Rocket Motors

No performance upgrade plan has been identified for the Atlas II solid rocket motors. However, since the proposed motors are a modification of existing motors, that modification could be made larger if there were a need for added performance.

c. Titan 34D, Liquid Rocket Engines

Current Titan 34D engine designs have numerous performance growth potentials. Previous studies indicate thrust and specific impulse improvements well within state-of-the-art capabilities through both manufacturing and design modifications. Some of these include electrical discharge machining (EDM) of injectors, performance balance changes, reduced injector fuel film cooling, turbopump modifications, reduced hydraulic resistances, tighter manufacturing tolerances and increased combustion chamber area ratios.

d. Atlas Liquid Rocket Engines

(TBD)

II. BOOSTER COST ESTIMATES

The booster cost estimates include all elements required to compare a DOD, Shuttle only, launch scenario with a launch scenario wherein two DOD missions per year are placed on commercial Expendable Launch Vehicles (ELVs). The cost comparisons reflect Air Force use of two commercial ELVs - the $T34D_7$/Centaur G' or the Atlas II/ Centaur G'. Also examined, but not pursued in equal depth because of considerably higher costs, was a Shuttle derived vehicle (SRB-X) with comparable performance capability. Analyses were performed to determine sensitivities to the cost forcing assumptions. Factors considered in these comparisons include:

- Costs incurred through ELV development, production and launch.
- Cost avoidance accrued from Shuttle flight charges.
- Savings accrued through reduced Shuttle security expenditures.
- Shuttle flight rate effects.
- Effect of dual integration of selected Air Force payloads.

These factors, when applied against the FY86 POM mission model, comprise the basis for comparison of the two launch scenarios. A risk assessment addressing these cost estimates is presented in Section IV. A summary of the acquisition and operational cost estimates for the SRB-X launch vehicle is included.

A. <u>ELV Cost Estimates</u>

The development and operations costs for the $T34D_7$/Centaur G' and Atlas II/Centaur G' vehicles capable of launching DOD Shuttle equivalent payloads reflect contractor cost estimates evaluated and adjusted by Air Force analysis. These cost estimates are based upon a first quarter FY85 program go-ahead and an early FY89 ILC. Payment for the vehicles will be made in January of the year prior to launch, identical to Shuttle payment.

1. <u>$T34D_7$/Centaur G'</u>

The $T34D_7$/Centaur G' represents modifications made to the T34D and the Centaur G' as described in Section I. The cost estimates, are summarized in Figure AII-5. A cost risk assessment of these costs is presented in Section IV. The $T34D_7$ and the Centaur G' will be procured on a commercial basis separately from the two contractors, each acting as associate contractors. The $T34D_7$ contractor will be the overall launch vehicle integration contractor.

a. Cost Assumptions

- The estimate represents a commercial cost approach developed during the Titan proposal activity which resulted in a firm fixed price bid to Intelsat for these vehicles in 1983.

- Range, propellants, government facility usage and program management costs are included in the estimate.

- Software independent verification and validation costs have been included.

- The costs assume that existing environmental impact statements, approvals and range safety waivers apply.

- The existing mission success system will be used on this program with all the disciplines currently employed.

- Costs for holding critical production, launch crew critical skills, and any vendor start up costs prior to Program go-ahead have been included.

b. Cost Estimates

The estimates of the $T34D_7$ non-recurring costs (excluding cost of money) are presented in Figure AII-1. The recurring costs (excluding cost of money) for production rates of two and four vehicles per year (launch rate of two per year) are presented in Figure AII-2. Added to the costs are estimates of government launch support and range costs. The costs, reflecting a production of four vehicles per year, have been structured to maintain a production capability through the five launch years by the retention of critical skills and facilities. Because of the lower cost of the four vehicle per year production rate and the contractor's stated guarantee of the five year production capability, this rate has been selected as the cost data base. A summary comparing the costs for the various production and launch rates for the total vehicle buys considered is presented in Figure AII-3. Included in these costs are estimates for the cost-of-money required for financing of both vehicle development and production costs. Centaur G' costs are presented in Figure AII-4.

APPENDIX

T34D7 Non-Recurring Cost Estimate.1)
(Millions of FY83 Dollars)

Booster (T34D7)	
Airframe Development and Integration	37
Guidance/Avionics-Program Support	1
Liquid Engine-Stage II Development	5
Solids-SRM Segment Development	26
Logistics and Spares 2)	--
Payload Fairing Development - 200 In. Dia.	21
Launch Site Refurbishment and Modification	40
Program Reserve	30
Total Non-Recurring	160

Note: 1) No cost-of-money included.
2) Logistics & Spares included in Recurring Costs.

Figure AII-1

APPENDIX

T34D7 Recurring Cost Estimate [1]
(Millions of FY83 Dollars)

	10 Vehicle Buy (Production/Launch Rate)	
	2/2	4/2
Booster		
Airframe	24.5	17.0
Guidance/Avionics	5.5	4.1
Liquid Engines	13.0	9.6
Solids	25.8	20.2
Logistics/Spares [2]	--	--
Sub-Total	68.8	50.9
Payload Fairing - 200 In. Dia.	12.6	11.8
Launch Services	16.8	16.8
Contingency Reserve [3]	--	--
Sub-Total	98.2	79.5
Government Launch, Program and Range Support	10.5	10.5
Total Recurring	108.7	90.0

Note: 1) No cost-of-money included.
2) Included in each booster element, in line with contractor historical cost data base.
3) Estimate incorporates 5% allowance in separate cost elements to provide for historical cost variances.

Figure AII-2

 Contractor restricted data-competition sensitive

T34D$_7$ Total Program Cost Per Flight Estimate
(Millions of FY83 Dollars)

Production Rate	Launch Rate	Total Vehicles	Total Costs NonRec	Rec	Cost of Money	Total	Unit Cost
4	2	10	160	900	93.0	1153	115.3
4	2	14	160	1263	116.0	1539	109.9
4	4	20	160	1600	152.0	1912	95.6
4	4	28	160	2240	210.0	2610	93.2

Figure AII-3

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APPENDIX

Centaur G' Total Program Cost Per Flight Estimate
(Millions of FY83 Dollars)
(For $T34D_7$)

	NON-RECURRING	RECURRING 10 Vehicle Buy (Production/Launch Rate) 4/2
Centaur	39.4	29.8
GSE/Site Mods	19.3	-
Logistics/Spares	5.5	5.4
Launch Services [1]	—	6.6
Subtotal [2]	64.2	41.8
Pro-Rate Non-Recurring (10 Vehicles)		6.4
Government Launch Support		3.5
Financing (Cost-of-money)		3.3
Total		55.0

Note: 1) Launch rate of four per year would reduce contractor launch services two million per launch.
2) The fairing is included in the $T34D_7$ costs.

Figure AII-4

 Contractor restricted data-competition sensitive

T34D$_7$/Centaur G' Total Program Cost Per Flight Estimate 1), 2), 3)
(Millions of FY83 Dollars)

Production Rate	Launch Rate	Total Vehicles	T34D$_7$ 4)	Centaur G' 5)	T34D$_7$/Centaur G'
4	2	10	115.3	55.0	170.3
4	2	14	109.9	53.2	163.1
4	4	20	95.6	49.8	145.4
4	4	28	93.2	48.9	142.1

Note:
1) Recurring unit cost of hardware.
2) Cost of development amortized over total vehicles shown in each case.
3) Government launch, program and range support.
4) Reference Figure AII-3.
5) Reference Figure AII-4.

Figure AII-5

2. Atlas II/Centaur G'

The Atlas II/Centaur G' represents modifications to the Atlas IIB and the Centaur G' as described in Section I. The cost estimates are summarized in Figure AII-10. The same general cost assumptions made for the $T34D_7$/Centaur G' (Section II.A.1.a) apply to these estimates. A cost risk assessment of these costs is presented in Section IV. Note that the excursions for various production quantities and launch rates done for $T34D_7$ are not repeated for Atlas II. However, it can be assumed that the same general relationships apply.

a. Cost Estimates

The estimates of the Atlas II nonrecurring costs (excluding cost of money) are presented in Figure AII-6. The recurring costs (excluding cost of money) for a production rate of four vehicles per year and a launch rate of two vehicles per year is presented in Figure AII-7. Added to these costs are estimates for government launch support and range costs. A summary of the total vehicle buy is presented in Figure AII-8. Included in the cost is an estimate for the cost of money for financing of both vehicle development and production costs. Centaur G' costs are presented in Figure AII-9.

APPENDIX

ATLAS II Non-Recurring Cost Estimate [1]
(Millions of FY83 Dollars)

Booster Development	
Airframe	208.4
Guidance/Avionics [2]	--
Liquid Engines	72.3
Solids	16.3
Logistics and Spares	53.1
Payload Fairing - 200 In. Dia. [3]	--
Launch Site Refurbishment and Modification	54.7
Program Reserve	46.8
Total Non-Recurring	451.6

Note: 1) No cost-of-money included.
2) Guidance/Avionics costs are included in Centaur G' costs.
3) Fairing is included in the Centaur G' costs.

Figure AII-6

APPENDIX

Atlas II Recurring Cost Estimate [1]
(Millions of FY 83 Dollars)

	10 Vehicle Buy (Production/Launch Rate) 4/2
Booster	
Airframe	26.9
Guidance/Avionics [2]	--
Liquid Engines	20.0
Solids	5.9
Logistics/Spares	8.3
Sub-Total	61.1
Payload Fairing - 200 In. Dia. [3]	--
Launch Services	8.6
Contingency	12.8
Sub-Total	82.5
Government Launch, Program and Range Support	14.3
Total Recurring	96.8

Note: 1) No cost-of-money included.
2) Guidance/Avionics is included in the Centaur G' costs.
3) Fairing is included in the Centaur G' costs.

Figure AII-7

Atlas II Total Program Cost Per Flight Estimate
(Millions of FY83 Dollars)

Production Rate	Launch Rate	Total Vehicles	Total Costs NonRec	Total Costs Rec	Cost of Money	Total	Unit Cost
4	2	10	451.6	968.0	183.0	1602.6	160.3

Figure AII-8

APPENDIX

Centaur G' Total Program Cost Per Flight Estimate
(Millions of FY83 Dollars)
(For Atlas II)

	NON-RECURRING	RECURRING 10 Vehicle Buy (Production/Launch Rate) 4/2
Centaur	34.6	26.1
GSE/Site Mods [1]	-	-
Logistics/Spares [1]	-	-
Launch Services [1]	-	-
Payload Fairing - 200 In. Dia.	28.6	10.8
Subtotal	63.2	36.9
Pro-Rate Non-Recurring (10 Vehicles)		6.3
Government Launch Support [1]		-
Financing (Cost-of-money)		3.3
Total		46.5

Note: 1) Costs are included in Atlas II costs.

Figure AII-9

Atlas II/Centaur G' Total Program Cost Per Flight Estimate 1), 2), 3)

(Millions of FY83 Dollars)

Production Rate	Launch Rate	Total Vehicles	Atlas II 4)	Centaur G' 5)	Atlas II/Centaur G'
4	2	10	160.3	46.5	206.8

Note:
1) Recurring unit cost of hardware.
2) Cost of development amortized over a 10 vehicle buy.
3) Government launch, program and range support.
4) Reference Figure AII-8.
5) Reference Figure AII-9.

Figure AII-10

APPENDIX

3. SRB-X/Centaur G'

The SRB-X/Centaur G' as defined in Section I offers a launch performance comparable to the commercial ELV. The cost estimates are summarized in Figure AII-15. A cost risk assessment of these costs is presented in Section IV. Because the SRB-X/Centaur G' does not appear to offer an economy of operations comparable to the commercial ELV, it has not been included in the launch comparison scenarios.

a. Cost Estimates

A summary of the Boeing Aerospace Company's cost estimate for the SRB-X, as contained in Report No. D180-273512 dated February 1983, submitted under NASA contract NAS 8-34722, for nonrecurring and recurring costs is presented in Figures AII-11 and AII-12 respectively. Added to these costs are estimates for government launch support and range costs. A summary of the total vehicle buy is presented in Figure AII-13. Centaur G' costs are presented in Figure AII-14.

SRB-X Non-Recurring Cost Estimate [1]
(Millions of FY83 Dollars)

Booster Development	
Airframe-Interstages, Integration, Management	285
Guidance/Avionics-Control Module & Software	151
Liquid Engines-T34D 2nd Stage	52
Solids-1st & 2nd Stage SRBs	139
Logistics and Spares	21
Payload Fairing - 200 In. Dia.	27
Launch Site Refurbishment & Modifications	68
Program Reserve [2]	—
Total Non-Recurring	743

Note: 1) Government developed, no cost-of-money considered.
2) Incorporated in individual elements.

Figure AII-11

APPENDIX

SRB-X Recurring Cost Estimate 1)
(Millions of FY83 Dollars)

	10 Vehicle Buy (Production/Launch Rate) 4/2
Booster	
Airframe-Interstages	8.2
Guidance/Avionics-Control Module	24.0
Liquid Engines - T34D 2nd Stage	12.2
Solids-1st & 2nd Stage SRBs	42.7
Logistics/Spares 2)	--
Sub-Total	87.1
Payload Fairing - 200 In. Dia.	7.4
Launch and Flight Operations 3)	20.3
Contingency Reserve 4)	--
Sub-Total	114.8
Government Launch, Program and Range Support	18.5
Total Recurring	133.3

Note: 1) Government developed and operated, no cost-of-money considered.
2) Included in each booster element.
3) Launch and flight operations use partial Shuttle cost data base.
4) Incorporated in individual elements.

Figure AII-12

SRB-X Total Program Cost Per Flight Estimate [1]
(Millions of FY83 Dollars)

Production Rate	Launch Rate	Total Vehicles	Total Costs NonRec [2]	Rec [3]	Cost of Money	Total	Unit Cost
4	2	10	743	1333	0	2076	207.6

Note: 1) No Cost-of-Money as SRB-X is Government Developed and Operated.
2) Reference Figure AII-10.
3) Reference Figure AII-11.

Figure AII-13

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Centaur G' Total Program Cost Per Flight Estimate
(Millions of FY83 Dollars)
(For SRB-X)

	NON-RECURRING	RECURRING 10 Vehicle Buy (Production/Launch Rate) 4/2
Centaur Vehicle	39.4	29.8
GSE/Site Mods 1)	-	-
Logistics/Spares	5.5	5.4
Launch Services	-	6.6
Sub-Total 2)	44.9	41.8
Pro-Rate Non-Recurring (10 Vehicles)		4.5
Government Launch Support		3.5
Financing (Cost-of-money) 3)		-
Total Recurring		49.8

Note: 1) Vehicle flown from Shuttle pad.
2) The fairing is included in the SRB-X costs.
3) Government developed and operated, no cost-of-money considered.

Figure AII-14

APPENDIX

SRB-X/Centaur G' Total Program Cost Per Flight Estimate 1), 2), 3)
(Millions of FY83 Dollars)

Production Rate	Launch Rate	Total Vehicles	SRB-X 4)	Centaur G' 5)	SRB-X/Centaur G'
4	2	10	207.6	49.8	257.4

Note:
1) Recurring unit cost of hardware.
2) Cost of development amortized over a 10 vehicle buy.
3) Government launch, program and range support.
4) Reference Figure AII-13.
5) Reference Figure AII-14.

Figure AII-15

APPENDIX

B. Shuttle Only/Commercial ELV Comparison

In accordance with national space policy guidance, the Shuttle only/commercial ELV comparison was performed using full-cost recovery Shuttle flight charges for the FY89-93 time frame in place of the current Memorandum of Agreement charge. The flight model (Figure AII-16) used in this analysis is the FY 86 POM model. Only Air Force programs were considered for commercial ELV launch. A summary of the factors considered in this comparison and the results are presented below. Sensitivities to this analysis are presented in Section IV.

APPENDIX

TRAFFIC MODEL

YEARLY TRAFFIC 1)	89	90	91	92	93	TOTAL
AFSC						
KSC	6	3-2/3	5-1/3	3-2/3	3-2/3	22-1/3
VAFB	1	1	1	1	1	5
SUBTOTAL	7	4-2/3	6-1/3	4-2/3	4-2/3	27-1/3
DOD OTHER						
KSC	4	2	0	2	2	10
VAFB	2	4	1	3	3	13
SUBTOTAL	6	6	1	5	5	23
NASA						
KSC	5	7-1/3	10-2/3	8-1/3	8-1/3	39-2/3
VAFB	0	0	0	0	0	0
SUBTOTAL	5	7-1/3	10-2/3	8-1/3	8-1/3	39-2/3
COMMERCIAL						
KSC	6	6	6	6	6	30
VAFB	0	0	0	0	0	0
SUBTOTAL	6	6	6	6	6	30
TOTAL	24	24	24	24	24	120

Note: 1) FY 86 POM TRAFFIC (EXTRAPOLATED TO FY 93)

Figure AII-16

APPENDIX

1. Two Orbiter/Year Cost Avoidance

Shuttle flight charge cost avoidance by flying two Air Force payloads per year on commercial ELVs is realized in the year prior to their launch. The Shuttle full-cost-recovery cost estimate was derived from the latest available NASA data, POP 83-2.

Shuttle flight cost prediction history as shown in the NASA 12 year average below, reflects a steady growth.

Data Source & Date	Total Flights	Costs FY 83 Dollars
Data Base, Jun 76	572	35.0
OMB Study, Sep 80	487	50.8
POP 81-2, Feb 82	362	74.0
NASA Comptr Assessed Data Base, Feb 82	234	111.5
POP 83-2, Aug 83 (12 Yr Avg)	232	132.7

NASA currently forecasts $112 million FY 83 dollars as the average cost per flight for the FY 89-93 time period. However, based upon cost history and the roughly 20% growth in their 12 year average flight charges from the Feb 82 to Aug 83 forecast, we have placed a 20% factor on the $112 million charge yielding a flight charge of $133 million FY 83 dollars. This cost avoidance is shown in the first line of the Air Force Impacts Figure. Reference Figures AII-18 and AII-20.

2. Optional Services Cost Avoidance

An additional cost avoidance is realized through the elimination of the optional service charge associated with each Shuttle flight. To date, optional service charges have ranged from $1 million to $5 million FY 83 dollars per flight. This cost spread evolves from mission and spacecraft flight planning and integration complexity. For this comparison, an average complexity and a cost of $3 million FY 83 dollars per flight was used.

3. Two Commercial ELV/Year Costs

The commercial ELV costs reflect a production rate of four vehicles per year and a launch rate of two vehicles per year (ten vehicle total). The vehicle payment will be made in January of the year prior to launch, identical to the Shuttle payment schedule. The costs used for the respective commercial ELVs are those presented in the preceding figures, AII-1 through AII-15.

4. Three Payload Dual Integrations

Three Air Force satellite programs were selected from the potential candidates described in Section III for dual integration with the Shuttle/Centaur and ELV/Centaur. First time integrations were assumed for the three programs as occurring at major block-changes. The remaining seven ELV flights were costed at the lower recurring integration rates.

a. Launch Vehicle, Non-Recurring Costs

The launch vehicle portion of the first time payload integration cost for a typical Air Force program is approximately $20 million FY 83 dollars on a Shuttle and $12 million on an ELV. However, when both integrations are accomplished together there is a $2 million dollar synergistic savings. As a result, the cost impact for a single first time ELV integration is estimated at $10 million. Therefore, for the three separate programs, a total first time integration cost of $30 million FY83 dollars was used.

b. Launch Vehicle, Recurring Savings

Recurring payload integration costs for the launch vehicle side are occasioned by partial repeat of the analytical and planning tasks necessary to validate any small changes that occurred since the prior launch. As a consequence of the reduced cost associated with a typical recurring payload integration on an ELV ($1 million FY 83 dollars) versus integration on a Shuttle ($5 million FY 83 dollars), a potential savings of $4 million per launch can be realized. Thus with seven remaining ELV launches, a total recurring payload integration savings of $28 million FY83 dollars was achieved.

c. Payload, Non-Recurring Costs

The payload program cost impacts based on dual integration of the DSP, DSCS III and MILSTAR spacecraft are as follows:

	Millions, FY83 $
DSP	10
DSCS III	10
MILSTAR	25

No delta payload recurring costs are included as they are estimated to be the same for flights on either the Shuttle or ELV.

A summary of pertinent comments regarding the specific payload integration follows.

1) DSP - Two transition periods were considered: mid-block transition for DSP 16/17 or transition at the DSP 18/19 block change. Since DSP 16/17 were designed only for STS/IUS missions, transition at the DSP 18/19 block buy was chosen. The cost impact for dual integration of DSP 18/19 block buy is considered minimal.

2) DSCS III - The cost impact for integrating the DSCS III to the ELV/Centaur is estimated as minimal, as it has previously been integrated to both the T34D/IUS and the STS/IUS.

3) MILSTAR - The MILSTAR program cost reflects spacecraft design impacts which are contingent upon refinement of the ELV and spacecraft design specifications. Further analysis may mitigate these cost impacts.

5. Security Savings

STS security elements which are flight rate dependent were reviewed and estimates made for savings which might be realized by the use of two commercial ELV flights per year.

Security related STS operations costs for JSC, KSC, and GSFC were extracted from the "NSTS Program Office - Level II Reimbursable Funding" Obligations Summary which was included as part of the Program Operations Plan (POP 83-2) submitted in August 1983. Shuttle Operations and Planning Center (SOPC) operations costs were provided by the Space Division STS Program Office as a POM estimate. An allocation of these costs into fixed and flight rate dependent cost categories was made using a 40%/60% ratio respectively. This 40%/60% ratio was developed as part of a Controlled Mode cost analysis briefed to the STS Steering Committee in August 1983. This same 40%/60% ratio was then also applied to the other NASA center security costs and to the SOPC costs.

The resultant estimated STS security costs are presented below in millions of FY 83 dollars:

	Flt Rate Per Yr	Total Cost Per Yr	Fixed Cost (40%) Per Yr	Flt Rate Variable Costs (60%) Per STS Flt
JSC	8	33.9	13.6	2.5
KSC	5	9.4	3.8	1.1
GSFC	8	4.9	2.0	0.4
DOD SOPC	8	75.8	30.3	5.7
Total Security			49.7	9.7

Based on the above cost estimates there is approximately a $50 million FY83 dollars fixed cost per year and a variable cost of $10 million per flight. NASA maintains that the costs are 100% fixed. While DOD disagrees with the NASA position and may achieve additional savings, the savings by flying two ELV flights per year was assumed to only affect the SOPC variable costs, which are approximately $12 million FY 83 dollars per year.

6. STS Impact Costs

A repeated argument used against maintaining ELVs as a complement to the Shuttle for assured access to space is the contention that the ELV flights will "steal" payloads from the Shuttle. Since a large portion of the Shuttle costs are to support a fixed operating base, reducing the flight model by even a single flight will require the remaining users to pay a somewhat larger share of the fixed base costs. For example, if, for the 24 flight per year mission model, one payload drops off the Shuttle to fly on an ELV, the remaining 23 users must pick-up a share of the Shuttle operating base costs previously paid by the ELV payload. While this is certainly true, it assumes that the services provided by the Shuttle are not significant enough to attract another payload to replace the one moved to the ELV. Such an assumption belies the logic and efficiencies upon which the Shuttle concept was sold, and is very unlikely to occur. There is little doubt that the two missions per year moved to ELVs could be resold to commercial, foreign, and/or government users ready to take advantage of the unique services offered by the Shuttle. In fact, what might be in doubt is the Shuttle fleet's ability to handle the large potential flight rate. Presently, Shuttle facilities are sized to handle few more than 24 flights per year. The President, in his recent State of the Union Message recognized the enormous potential that Space holds for commerce today, and cautioned that "the market for space transportation could surpass our capacity to develop it." Therefore, to relieve the expected pressure on the spaceflight manifest, the President encouraged those interested in putting payloads into space to look to the private sector, specifically Expendable Launch Vehicles, for relief.

APPENDIX

NASA recognizes the abundance of possible Shuttle payloads and in September 83 published a Change Request to study the required upgrade of their Shuttle facilities to handle a flight rate growing from the present 24 per year to 28, 34, and 40 per year in FYs 89, 90, and 91 respectively. The subsequent approval of the Space Station can only serve to strengthen the demand for Shuttle launch services during this time frame, and strongly neutralize the concern that Shuttle missions would be lost without replacement as a result of two DOD ELV flights per year.

A final factor mitigating the concern over Shuttle payload losses to DOD ELVs is a technical consideration. As might be expected, the processing of the Centaur Upper Stage aboard the Shuttle is considerably more complex than processing simpler upper stages. For example, the processing of the Centaur for the NASA planetary mission in the Spring of 1986 takes approximately twice as long as for a "normal" mission. Therefore, because of the direct impact Shuttle turnaround time has on maintaining the flight rate, NASA has stated that the Centaur processing for this mission will effectively cause the loss of <u>one additional mission</u> from the manifest. Simply put, every time we fly Centaur on the Shuttle we lose a Shuttle mission due to Centaur processing time. Therefore, flying the Centaur on another vehicle (ELV) would regain this lost Shuttle flight. Taking a Centaur payload <u>off</u> the Shuttle allows <u>two</u> Shuttle missions to be flown in its stead. This obviously would benefit all other Shuttle users sharing the costs of the fixed operating base.

Eventually, follow-on Shuttle/Centaur missions will not require double the normal flow times. Estimates indicate that these can be reduced to about 2/3 more than the average flow time and thus only 2/3 of a flight would be lost for each Shuttle Centaur flight.

Applying these predictions to the concern of ELVs "stealing" payloads from the Shuttle leads to a much less than one-for-one ratio. At most, two ELVs per year would impact the Shuttle about 2/3 of one flight -- if that 2/3 of a flight could not be resold. And, as stated above, the probability of not being able to resell that 2/3 of a flight per year appears very remote. To provide a sensitivity analysis for a complete spectrum of eventualities, this report includes the impact on other users if the DOD flies two missions per year (ELV/Centaur versus Shuttle/Centaur and the Shuttle flights are not resold. The cost impact on other users for each flight not resold is shown in Figure AII-17; approximately $4 million for KSC flights and $2.4 million for Vandenberg flights. The cumulative impact to the Air Force, other DOD users, and the Government as a whole is shown in this section. Although not a factor to the budget, the impact to foreign and commercial users is also indicated. In the case where two flights are resold, there is no cost impact, this represents our baseline case. The situation wherein one or none of these are resold is also shown. See Figures AII-19 and AII-21.

Cost Effect of Deleted Shuttle Flights

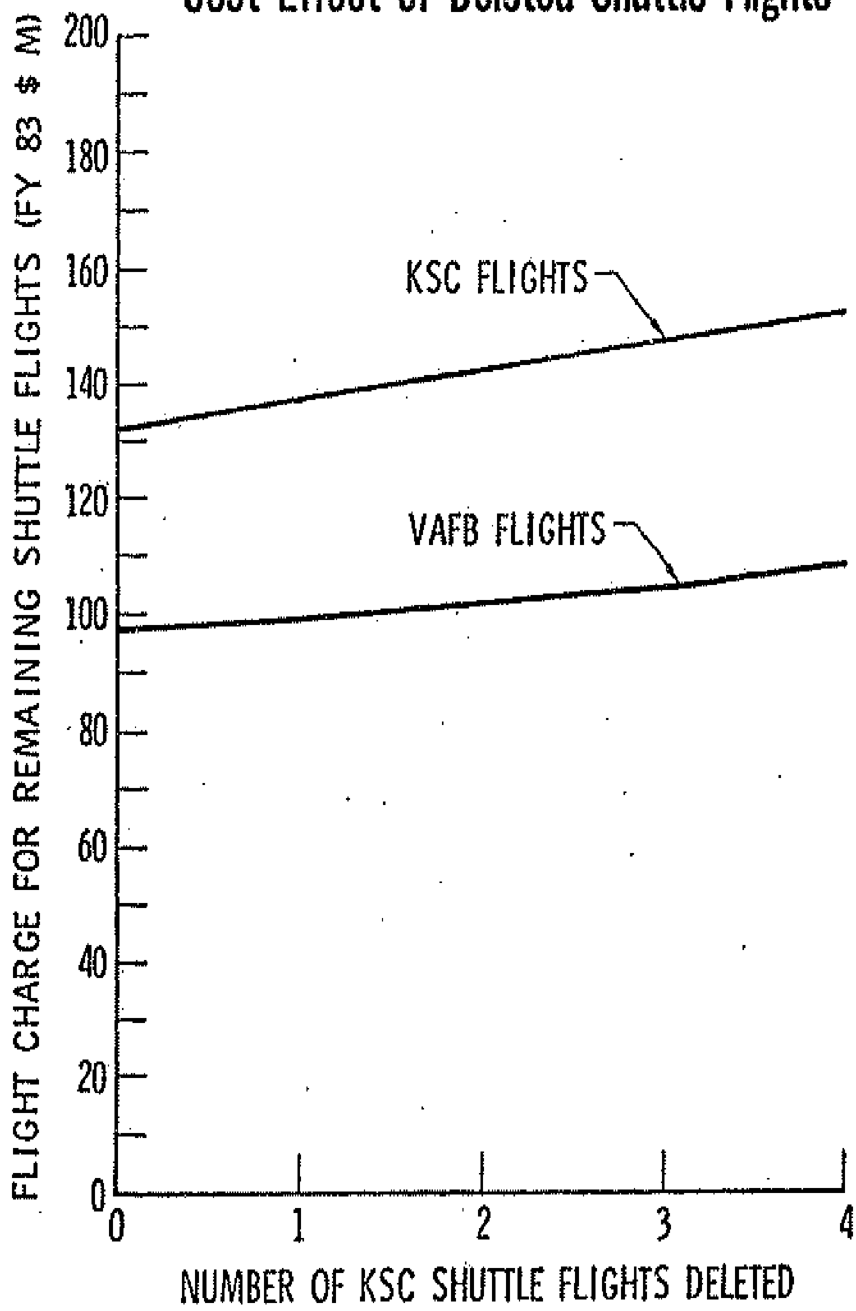

FIGURE AII-17

APPENDIX

C. Launch Scenario Comparison

Launch scenario comparisons were made where either the $T34D_7$/Centaur G' or Atlas II/Centaur G' vehicles were substituted for two Shuttle flights per year for a five year period. Figures AII-18 through AII-21 summarize impacts in then year dollars for the launch scenario comparisons.

1. $T34D_7$/Centaur G'

The $T34D_7$/Centaur G' versus Shuttle cost comparison for the Air Force is presented in Figure AII-18. This table identifies a cost savings of $147 million then year dollars when all offsetting cost impacts are considered.

The cost to the other users resulting from the substitution of two $T34D_7$/Centaur G' for two Shuttle flights is presented in Figure AII-19. This table shows the Air Force cost impact as well as the cost impacts for all remaining government and commercial/foreign Shuttle users in the unlikely event all or some portion of the vacated Shuttle flights are not resold.

Considerations of orbiter amortization costs of $20 million then year dollars per flight increases these savings by a total of $200 million then year dollars. The orbiter amortization cost savings are calculated based upon a $2 billion cost for a replacement orbiter divided by an assumed life of 100 flights. Each vacated Shuttle mission therefore delays procurement of a replacement orbiter with a value of $20 million per mission. Similar changes and offsets are reflected in the tabulations for one and zero Shuttle flight deletions. In these instances it has been assumed the Shuttle flights were resold by NASA.

AIR FORCE IMPACTS - $T34D_7$
(FULL COST RECOVERY - MILLIONS OF TY DOLLARS)

FY	85	86	87	88	89	90	91	92	93	TOTAL
2 ORB/YR				-355	-380	-405	-435	-465		-2040
OPT SERV				-8	-9	-9	-10	-11		-47
2 ELV/YR				350	375	395	420	440		+1980
3 PROG DUAL INTEG (LV)	3	5	8	13	9	2				+40
7 SAT REC INTEG (LV)					-3	-9	-13	-14	-8	-47
P/L IMPACT	10	15	13	11	5					+54
SECURITY SAVINGS					-16	-17	-17	-18	-19	-87
STS IMPACT COST	0	0	0	0	0	0	0	0	0	0
TOTAL	+13	+20	+21	+11	-19	-43	-55	-68	-27	-147

ASSUMPTIONS:
ELV DEVELOPMENT AMORTIZED OVER 10 VEHICLES
AIR FORCE FLIES 2 ELVs/YR, NASA RESELLS TWO AIR FORCE DELETED SHUTTLE FLIGHTS
NOTE: MINUS (-) INDICATES SAVINGS

FIGURE AII-18

NATIONAL IMPACTS - $T34D_7$ 10 FEBRUARY 1984

(FULL COST RECOVERY - MILLIONS OF TY DOLLARS)

FY	85-87	88	89	90	91	92	93	TOTAL
2 STS FLIGHTS RESOLD								
DOD								
AF	54	11	-19	-43	-55	-68	-27	-147
OTHER	0	0	0	0	0	0	0	0
NASA	0	0	0	0	0	0	0	0
GOV'T TOTAL	54	11	-19	-43	-55	-68	-27	-147
COMM/FOREIGN	0	0	0	0	0	0	0	0
1 STS FLIGHT RESOLD								
DOD								
AF	54	36	-4	-18	-40	-53	-27	-52
OTHER	0	30	25	5	25	30	0	+115
NASA	0	30	45	70	55	65	0	+265
GOV'T TOTAL	54	96	66	57	40	42	-27	+328
COMM/FOREIGN	0	35	35	40	45	45	0	+200
0 STS FLIGHTS RESOLD								
DOD								
AF	54	61	11	7	-25	-33	-27	+48
OTHER	0	60	55	10	50	55	0	+230
NASA	0	60	90	140	115	125	0	+530
GOV'T TOTAL	54	181	156	157	140	147	-27	+808
COMM/FOREIGN	0	70	70	80	85	90	0	395

NOTE: ORBITER AMORTIZATION WOULD RESULT IN AN ADDITIONAL 20 MILLION DOLLAR SAVINGS PER FLIGHT NOT SOLD

MINUS (-) INDICATES SAVINGS

FIGURE AII-19

Atlas II/Centaur G'

The Atlas II/Centaur G' versus Shuttle cost comparison for the Air Force is presented in Figure AII-20. This table identifies a cost impact of $288 million then year dollars when all offsetting cost impacts are considered.

The cost to the other users resulting from the substitution of two Atlas II/Centaur G' for two Shuttle flights is presented in Figure AII-21. This table shows the Air Force cost impacts as well as cost impacts for all remaining government and commercial/foreign Shuttle users in the unlikely event all or some portion of the vacated Shuttle flights are not resold.

Considerations of orbiter amortization costs of $20 million then year dollars per flight decreases these impacts by a total of $200 million then year dollars. The orbiter amortization cost savings are calculated based upon a $2 billion cost for a replacement Orbiter divided by an assumed life of 100 flights. Each vacated Shuttle mission therefore delays procurement of a replacement orbiter with a value of $20 million per mission. Similar changes and offsets are reflected in the tabulations for one and zero Shuttle flight deletions. In these instances it has been assumed the Shuttle flights were resold by NASA.

AIR FORCE IMPACTS - ATLAS II 10 FEBRUARY 1984
(FULL COST RECOVERY - MILLIONS OF TY DOLLARS)

FY	85	86	87	88	89	90	91	92	93	TOTAL
2 ORB/YR				-355	-380	-405	-435	-465		-2040
OPT SERV				-8	-9	-9	-10	-11		-47
2 ELV/YR				420	450	480	515	550		+2415
3 PROG DUAL INTEG (LV)	3	5	8	13	9	2				+40
7 SAT REC INTEG (LV)					-3	-9	-13	-14	-8	-47
P/L IMPACT	10	15	13	11	5					+54
SECURITY SAVINGS					-16	-17	-17	-18	-19	-87
STS COSTS	0	0	0	0	0	0	0	0	0	0
TOTAL	+13	+20	+21	+81	+56	+42	+40	+42	-27	+288

ASSUMPTIONS:
ELV DEVELOPMENT AMORTIZED OVER 10 VEHICLES
AIR FORCE FLIES 2 ELVs/YR, NASA RESELLS TWO AIR FORCE DELETED SHUTTLE FLIGHTS
NOTE: MINUS (-) INDICATES SAVINGS

FIGURE AII-20

USER COST IMPACTS - ATLAS II

10 FEBRUARY 1984

(FULL COST RECOVERY - MILLIONS OF TY DOLLARS)

FY	85-87	88	89	90	91	92	93	TOTAL
2 STS FLIGHTS RESOLD								
DOD								
AF	54	81	56	42	40	42	-27	+288
OTHER	0	0	0	0	0	0	0	0
NASA	0	0	0	0	0	0	0	0
GOV'T TOTAL	54	81	56	42	40	42	-27	+288
COMM/FOREIGN	0	0	0	0	0	0	0	0
1 STS FLIGHT RESOLD								
DOD								
AF	54	106	71	67	55	57	-27	+383
OTHER	0	30	25	5	25	30	0	+115
NASA	0	30	45	70	55	65	0	+265
GOV'T TOTAL	54	166	141	142	135	152	-27	+763
COMM/FOREIGN	0	35	35	40	45	45	0	+200
0 STS FLIGHTS RESOLD								
DOD								
AF	54	131	86	92	70	77	-27	+483
OTHER	0	60	55	10	50	55	0	+230
NASA	0	60	90	140	115	125	0	+530
GOV'T TOTAL	54	251	231	242	235	257	-27	+1243
COMM/FOREIGN	0	70	70	80	85	90	0	395

NOTE: ORBITER AMORTIZATION WOULD RESULT IN AN ADDITIONAL 20 MILLION DOLLAR SAVINGS PER FLIGHT NOT SOLD

MINUS (-) INDICATES SAVINGS

FIGURE AII-21

III. PAYLOADS

A. Payload Identification

The payloads selected for the commercial ELV were selected on the basis of mission compatibility, schedule, and stability of launch-to-launch configuration. Since the commercial ELV utilizes a Centaur upper stage, having an interface and capability essentially identical to the DOD STS/Centaur, the integration tasks are minimized. The three programs selected have planned regular launches in the period under consideration. They are currently scheduled to fly on STS/Centuar, or are candidates for STS/Centaur. Considered in the selection was the schedule for new spacecraft design or major design block changes, since a new first time integration could conveniently be made a dual integration for commercial ELV and STS/Centaur. Details of this selection process are covered in the classified Annex.

B. Interface

The payload-to-Centaur interface of the commercial ELV/Centaur G' will be identical to the STS/Centaur G payload interface to the maximum extent possible, considering the presence of the payload fairing instead of the STS cargo bay, differences in interface loads, and launch site ground interfaces. The interface will be similar to the proposed DOD STS/Centaur G, Interface Control Document, Generic Centaur G-to-Satellite Vehicle (U) ICD 65-00320, Original Issue - November 30, 1983, Contract No. NAS-3-22901. The payload fairing interfaces are to be determined, but will provide a 15 foot diameter by 40 foot length STS equivalent payload envelope.

C. Integration

Payload integration consists of planning and engineering studies which are required to assure that a spacecraft's requirements are completely met by the launch system, and that successful launch operations will be achieved. These studies are accomplished by the spacecraft contractor, the launch system contractors, and responsible government agencies together, typically over a three year period for ELV's and four years for the STS (Figures AIII-1 and AIII-2). The payload integration activity encompasses requirements definition and management plans, interface designs and specifications, structural loads analyses, flight planning and other implementation activities. This process culminates in a final milestone flight readiness review where all contractors and agencies agree that the spacecraft and launch system are ready for launch.

First time payload integration involves a new combination of spacecraft and launch system, which requires iterative analyses to define the interface design and compatibility. Recurring payload integration consists of partial repeat of the analytical and planning tasks necessary to validate any small changes that occurred in the program since the prior launch. The cost estimates for first time and recurring payload integation are shown in Appendix AII.

Typical Payload Integration Schedule – Analysis

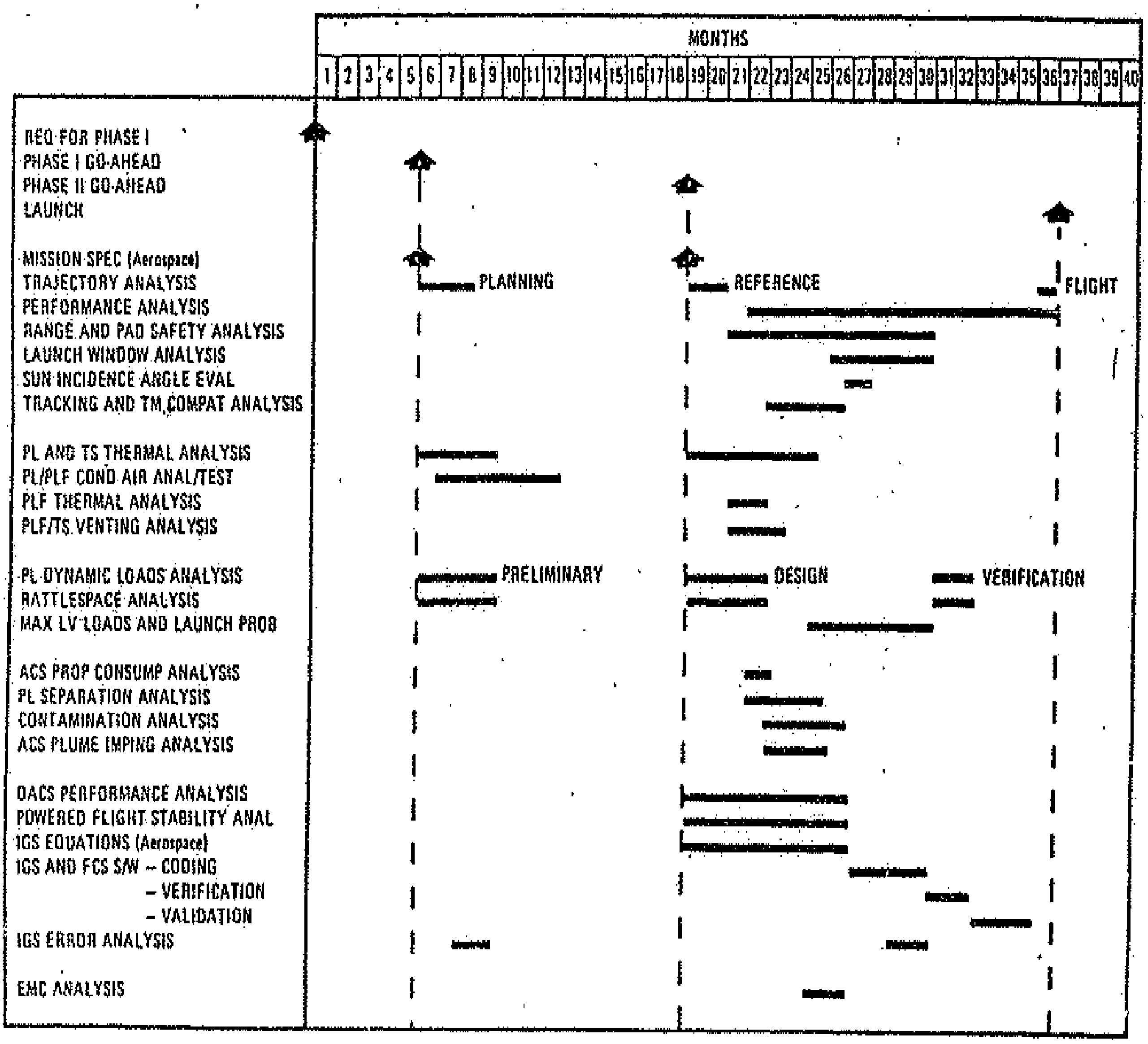

FIGURE AIII-1

IV. RISK ASSESSMENT

A. Technical/Schedu

1. Commercial ELV

The proposed upg
Titan $34D_7$ or Atlas II has few a
Comparatively, the Titan 34D,
percentage of flight proven c
previously investigated or deve
basically the Titan 34D with 7 s
an increased liquid propellant

The Atlas II inc
repackaged, enlarged diameter v
the current Atlas family of ve
rocket motors. This vehicle repr
existing Atlas family than does

The overall des
appropriate to both the Atlas a
present capabilities of the cont
risks in either configuration.

The design of the
For example, the engine syste
characterize the ignition sequen
Thus, there is some uncertainty
off event. This may result in l
and the spacecraft. Further, th
feed system demonstration and c
that could become a significant
risk for the Atlas II is therefo

For the $T34D_7$/Ce
examination in the funded concep
of the large diameter fairing cor
and schedule risk for the $T34D_7$/(

Both of the propo
launch site. In addition, the
program in 1977. Detailed descr
Appendix V (Launch Base Processin
work cannot be started early in t

2. SRB-X

The SRB-X explorat
risk assessment comparable to the
the data available it appears the
SRB-X is the proposed structural

IV. RISK ASSESSMENT

A. Technical/Schedule Risk

1. Commercial ELV

The proposed upgraded Expendable Launch Vehicle (ELV) using the Titan $34D_7$ or Atlas II has few areas to which a moderate risk can be attached. Comparatively, the Titan $34D_7$ has the lesser risk since it has a higher percentage of flight proven components and all major changes have been previously investigated or developed over the past 20 years. The vehicle is basically the Titan 34D with 7 segment solids rather than 5-1/2 segments, and an increased liquid propellant load.

The Atlas II incorporates many of the existing components in a repackaged, enlarged diameter vehicle and uses the basic design concepts of the current Atlas family of vehicles with the addition of strap-on solid rocket motors. This vehicle represents a more significant extrapolation of the existing Atlas family than does the $T34D_7$ in the Titan family.

The overall design, development and producibility issues appropriate to both the Atlas and Titan configurations are well within the present capabilities of the contractors involved. There are no high technical risks in either configuration.

The design of the Atlas II is relatively immature at this time. For example, the engine system is not defined and there is no data to characterize the ignition sequence, thrust build-up, thrust differential, etc. Thus, there is some uncertainty in vehicle and spacecraft loads for the lift-off event. This may result in late definition of loads on the launch vehicle and the spacecraft. Further, the Atlas II liquid engine delivery, integrated feed system demonstration and cluster firing is a large engineering effort that could become a significant schedule driver. The schedule and technical risk for the Atlas II is therefore assessed as being moderate.

For the $T34D_7$/Centaur G', areas which require continued examination in the funded concept definition study are stability and control of the large diameter fairing configuration and vehicle performance. Technical and schedule risk for the $T34D_7$/Centaur G' are assessed as low.

Both of the proposed ELVs will require modifications to the launch site. In addition, the site has not been used since the Titan IIIE program in 1977. Detailed description of the work required can be found in Appendix V (Launch Base Processing). Some schedule risk could result if the work cannot be started early in the program, as planned.

2. SRB-X

The SRB-X exploratory concepts are too preliminary to permit a risk assessment comparable to the other two ELV configurations. However, from the data available it appears the largest area of technical concern with the SRB-X is the proposed structural arrangement attaching the boosters to the

core vehicles. This configuration was chosen to achieve the correct SRM spacing to allow the SRB-X to be launched from an existing Shuttle launch pad. To make this structure stiff enough to preclude vehicle control problems, extensive vehicle weight growth may be encountered with a resulting loss in vehicle performance.

While the basic Solid Rocket Booster elements (Stage I) are flight proven, another area of technical concern is the highly modified SRM second stage. Only two of the standard four solid motor segments are used. In addition, a completely new nozzle is required to optimize high altitude performance.

The SRB-X's shortfall in terms of schedule, when compared to the Titan or Atlas II, is that it cannot be developed in time to meet the required ILC. Current projections indicate an SRB-X development program would take 54 months from ATP to first flight. Prior to ATP, full scale concept selection and competitive source selection activities would add another 24 months to the program, bringing the total vehicle development time to 78 months. This means the earliest the vehicle could fly would be mid-to-late 1990.

B. Cost Risk

The cost risk assessment examines costs for both completeness and reasonableness, and addresses both Shuttle and ELV cost considerations.

1. ELV Cost Estimates

The ELV cost risk assessment addresses the risk of growth in the costs currently projected for the commercial ELV concept. The cost estimates for the ELVs are based upon recent historical cost data and contractor estimates supplemented by Space Division analysis.

a. $T34D_7$/Centaur G'

Both the $T34D_7$ and the Centaur G' are adaptations of vehicles that are currently operational. The modifications required to transform the T34D to the $T34D_7$ and integrate it to the Centaur have been extensively examined. The non-recurring cost presented in Figure AII-1 identifies an estimate of $160 million FY 83 dollars. Contained within this estimate is $15 million dollars which the Air Force has put in as a reserve to cover the following elements of concern:

1) Titan Core Development and Integration. The contractor estimate may be optimistic based on T34D development costs.

2) SRM Segment Development. The contractor estimate reflects two all-up SRM firings. An additional firing is believed necessary.

3) Liquid Engine Stage II Development. The contractor estimate is based upon a first-time successful firing of the second stage liquid rocket engine with modification for extended burn time. This approach may be optimistic and an additional firing may be required.

While the contractor's estimate provides $15 million dollars for growth, it is felt this additional reserve is still justified as protection against unknowns.

The contractor's estimate for recurring costs as presented in Figure AII-2 has been reviewed and found comparable to the Space Division estimates based on historical data. An item-by-item review of the elements disclosed slight variances, but when the total estimates were compared, the overall variance was negligible.

The Centaur G' is scheduled for first launch on the Shuttle in 1986. The cost for modification of this vehicle and its launch site for use with the $T34D_7$, along with its recurring cost for a ten vehicle buy, are presented in Figure AII-4. While sufficient data is not available at this time to make an element-by-element analysis, the cost is believed to be both complete and reasonable. Furthermore, the total cost per launch of about $55 million FY 83 dollars compares favorably relative to the $50 million dollar cost of the Centaur G for launch on the Shuttle as priced by NASA in their

APPENDIX

letter to Space Division of 21 September 1983.

b. Atlas II/Centaur G'

Due to the lack of data supporting the top level contracto cost estimates, detailed assessment of the Atlas II/Centaur G' could not b made. However, historical data on a small Atlas, scaled to the Atlas II indicates both the recurring and non-recurring costs are somewhat overstated.

c. SRB-X/Centaur G'

The SRB-X costs, obtained from a NASA funded study, appear t(be reasonable to a first approximation.

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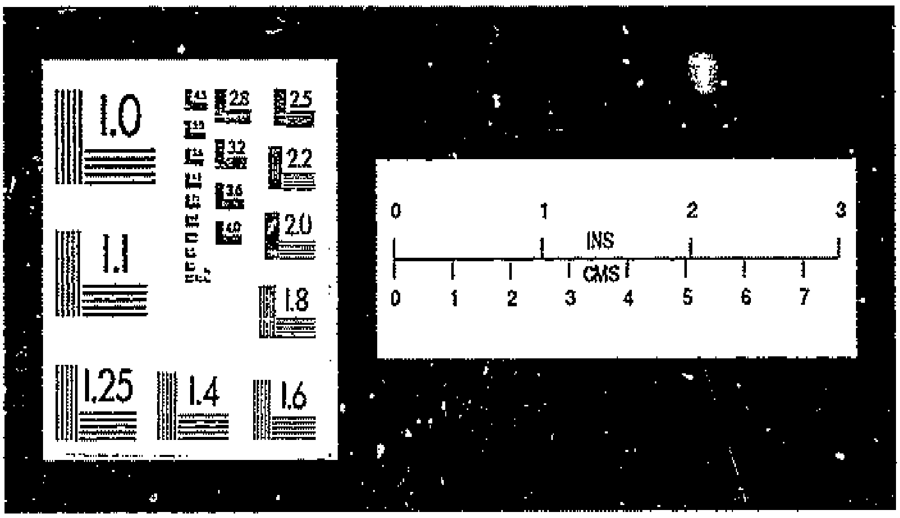

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APPENDIX

2. Shuttle Only/Commercial ELV Comparison

a. Shuttle Pricing Policy

This analysis used the full-cost-recovery Shuttle cost per flight of $133 million FY 83 dollars. The validity of this estimate is discussed in the cost section. It assumes a 20% growth in NASA predicted cost based on historical data. Should the current Shuttle pricing policy subsidizing Shuttle launches to all users be retained in the out years, the cost to DOD of Shuttle would not be sufficient to cover the costs of substituting ELVs. Figure AIV-1 shows this cost trade.

b. Shuttle Launch Rate

Two alternative Shuttle launch rates were examined, a 16 flight per year model and a 40 flight per year model. For comparative purposes, only one ELV option was used, a $T34D_7$.

1) 16 Flight Per Year Model - A launch scenario comparison for the 16 flight per year model (13 at KSC and 3 at VAFB) was made wherein two commercial ELV flights were substituted for two Shuttle flights. The results of this comparison are presented in Figures AIV-2 and AIV-3 for the Air Force and other Shuttle users respectively.

The full-cost-recovery Shuttle cost per flight used for the 16 flight model was $177.5 million FY 83 dollars. The cost impact to remaining Shuttle flights for each flight not resold was $9.6 million for KSC and $5.5 million for VAFB. Using these costs the Air Force realized a savings of $837 million then year dollars versus the cost savings of $147 million experienced for the 24 flight per year model.

AIR FORCE IMPACTS - T34D7 (CURRENT PRICING POLICY - MILLIONS OF TY DOLLARS)

10 FEBRUARY 1984

FY	85	86	87	88	89	90	91	92	93	TOTAL
2 ORB/YR				-155	-165	-180	-190	-205		-895
OPT SERV				-8	-9	-9	-10	-11		-47
2 ELV/YR				350	375	395	420	440		+1980
3 PROG DUAL INTEG (LV)	3	5	8	13	9	2				+40
7 SAT REC INTEG (LV)					-3	-9	-13	-14	-8	-47
P/L IMPACT	10	15	13	11	5					+54
SECURITY SAVINGS					-16	-17	-17	-18	-19	-87
STS IMPACT COSTS	0	0	0	0	0	0	0	0	0	0
TOTAL	+13	+20	+21	+211	+196	+182	+190	+192	-27	+998

ASSUMPTIONS:

- ELV DEVELOPMENT AMORTIZED OVER 10 VEHICLES
- AIR FORCE FLIES 2 ELVs/YR
- MINUS (-) INDICATES SAVINGS

FIGURE AIV-1

AIR FORCE IMPACTS - T34D$_7$ 10 FEBRUARY 1984
(16 FLIGHT MODEL SENSITIVITY)
(FULL COST RECOVERY - MILLIONS OF TY DOLLARS)

FY	85	86	87	88	89	90	91	92	93	TOTAL
2 ORB/YR				-475	-505	-545	-580	-625		-2730
OPT SERV				-8	-9	-9	-10	-11		-47
2 ELV/YR				350	375	395	420	440		+1980
3 PROG DUAL INTEG (LV)	3	5	8	13	9	2				+40
7 SAT REC INTEG (LV)					-3	-9	-13	-14	-8	-47
P/L IMPACT	10	15	13	11	5					+54
SECURITY SAVINGS					-16	-17	-17	-18	-19	-87
STS IMPACT COSTS	0	0	0	0	0	0	0	0	0	0
TOTAL	+13	+20	+21	-109	-144	-183	-200	-228	-27	-837

ASSUMPTIONS:
ELV DEVELOPMENT AMORTIZED OVER 10 VEHICLES
AIR FORCE FLIES 2 ELVs/YR, NASA RESELLS TWO AIR FORCE DELETED SHUTTLE FLIGHTS
NOTE: MINUS (-) INDICATES SAVINGS

FIGURE AIV-2

USER COST IMPACTS - T34D7
(16 FLIGHT MODEL SENSITIVITY)
(MILLIONS OF TY DOLLARS)

10 FEBRUARY 1984

FY	85-87	88	89	90	91	92	93	TOTAL
2 STS FLIGHTS RESOLD								
DOD								
AF	54	-109	-144	-183	-200	-228	-27	-837
OTHER	0	0	0	0	0	0	0	0
NASA	0	0	0	0	0	0	0	0
GOV'T TOTAL	54	-109	-144	-183	-200	-228	-27	-837
COMM/FOREIGN	0	0	0	0	0	0	0	0
1 STS FLIGHT RESOLD								
DOD								
AF	54	-44	-109	-123	-165	-188	-27	-602
OTHER	0	70	60	10	65	70	0	+275
NASA	0	45	80	140	105	115	0	+485
GOV'T TOTAL	54	71	31	27	5	-3	-27	+158
COMM/FOREIGN	0	0	0	0	0	0	0	0
0 STS FLIGHTS RESOLD								
DOD								
AF	54	21	-79	-58	-125	-148	-27	-362
OTHER	0	140	125	20	125	135	0	+545
NASA	0	85	160	275	215	230	0	965
GOV'T TOTAL	54	246	206	237	215	217	-27	+1148
COMM/FOREIGN	0	0	0	0	0	0	0	0

NOTE: ORBITER AMORTIZATION WOULD RESULT IN AN ADDITIONAL 20 MILLION DOLLAR SAVINGS PER FLIGHT NOT SOLD.
MINUS (-) INDICATES SAVINGS

FIGURE AIV-3

2) 40 flight per year model - This model was selected to represent an upper boundary case. Support of this 40 flight model (30 flights at KSC and 10 flights at VAFB) necessitates funding expenditures for the fifth orbiter and for additional facilities at both KSC and VAFB. These investment costs are very large and should be used in evaluating cost trades. However, because of their uncertainty and impact on the cost of Shuttle, they have not been included in the Shuttle cost per flight analysis.

A launch scenario comparison for the 40 flight per year model was made wherein two commercial ELV flights were substituted for two Shuttle flights. The results of this comparison are presented in Figures AIV-4 and AIV-5 for the Air Force and other Shuttle users respectively. In this comparison, the DOD flights were those presented in Figure AII-16 and all flight rate growth was assumed in NASA and Commercial/Foreign flights.

The full-cost-recovery Shuttle cost per flight used for the 40 flight model was $100.0 million FY 83 dollars. The cost impact to remaining Shuttle flights for each flight not resold was $1.6 million for KSC and $0.8 million for VAFB. Using these costs the Air Force experienced a cost impact of $353 million then year dollars versus the cost savings of $147 million experienced for the 24 flight per year model. The large variation in cost impact to the DOD results from the reduced savings realized through deletion of the lower cost Shuttle flights. The impacts do not factor in the more than $2 billion capital investment estimated as required to achieve the 40 per year flight rate.

AIR FORCE IMPACTS - T34D7 | 10 FEBRUARY 1984
(40 FLIGHT MODEL SENSITIVITY)
(FULL-COST-RECOVERY - MILLIONS OF TY DOLLARS)

FY	85	86	87	88	89	90	91	92	93	TOTAL
2 ORB/YR				-270	-285	-305	-330	-350		-1540
OPT SERV				-8	-9	-9	-10	-11		-47
2 ELV/YR				350	375	395	420	440		+1980
3 PROG DUAL INTEG (LV)	3	5	8	13	9	2				+40
7 SAT REC INTEG (LV)					-3	-9	-13	-14	-8	-47
P/L IMPACT	10	15	13	11	5					+54
SECURITY SAVINGS					-16	-17	-17	-18	-19	-87
STS IMPACT COSTS	0	0	0	0	0	0	0	0	0	0
TOTAL	+13	+20	+21	+96	+76	+57	+50	+47	-27	+353

ASSUMPTIONS:
- ELV DEVELOPMENT AMORTIZED OVER 10 VEHICLES
- AIR FORCE FLIES 2 ELVs/YR, NASA RESELLS TWO AIR FORCE DELETED SHUTTLE FLIGHTS

NOTE: MINUS (-) INDICATES SAVINGS

FIGURE AIV-4

USER COST IMPACTS - T34D7
(40 FLIGHT MODEL SENSITIVITY)
(MILLIONS OF TY DOLLARS)

10 FEBRUARY 1984

FY	85-87	88	89	90	91	92	93	TOTAL
2 STS FLIGHTS RESOLD								
DOD								
AF	54	96	76	57	50	47	-27	+353
OTHER	0	0	0	0	0	0	0	0
NASA	0	0	0	0	0	0	0	0
GOV'T TOTAL	54	96	76	57	50	47	-27	+353
COMM/FOREIGN	0	0	0	0	0	0	0	0
1 STS FLIGHT RESOLD								
DOD								
AF	54	106	81	67	55	57	-27	+393
OTHER	0	10	10	5	10	10	0	+45
NASA	0	25	35	40	45	45	0	+190
GOV'T TOTAL	54	141	126	112	110	112	-27	+628
COMM/FOREIGN	0	25	30	30	35	35	0	+155
0 STS FLIGHTS RESOLD								
DOD								
AF	54	116	86	77	60	62	-27	+428
OTHER	0	20	20	5	20	20	0	+85
NASA	0	50	70	85	85	90	0	+380
GOV'T TOTAL	54	186	176	167	165	172	-27	+893
COMM/FOREIGN	0	55	55	60	65	70	0	+305

NOTE: ORBITER AMORTIZATION WOULD RESULT IN AN ADDITIONAL 20 MILLION DOLLAR SAVINGS PER FLIGHT NOT SOLD.
MINUS (-) INDICATES SAVINGS

FIGURE AIV-5

3. Dual Payload Integration

The cost impact of dual payload integration (Shuttle and commercial ELV) was based on the DSP, DSCS and MILSTAR being both logical selections and being representative of any new or major block change payloads. Should the number of payloads selected vary, the costs will vary accordingly. The risk in estimating costs for dual payload integration varies directly with payload maturity - a new or major block change payload will incur minimal design impact and only the cost of integration. The payloads selected were chosen to minimize risk.

4. Shuttle Security Savings

The Shuttle security savings were discussed in Section AII and presented in Figures AII-18 and AII-20. Although there is a disagreement between the Air Force and NASA over whether the NASA security costs are 100% fixed or some combination of fixed and variable, to insure conservatism in this analysis, only CSOC Shuttle Operations and Planning Complex variable cost savings were assumed. Another significant area of potential savings is in the deactivation of the NASA Controlled Mode System. The Controlled Mode is that capability at Johnson Space Center (JSC), which handles classified DOD launches. O&M costs for Controlled Mode total almost $50 million per year in the late '80s. While CSOC will handle about 8 DOD missions per year, any overflow to NASA JSC will require operation of the Controlled Mode. Offload of two Shuttle missions per year to ELVs could allow Controlled Mode to go into caretaker status with a savings of about $30 million per year. This savings was not included in the analysis.

5. Shuttle Cost Growth

The past growth in Shuttle cost per flight was accounted for in this analysis as discussed in the cost section of this appendix. (Reference Section AII, paragraph B1.)

6. Shuttle Turn-Around

The first use of Centaur in the Shuttle increases the Orbiter stay-time in the Orbiter Processing Facility (OPF) from the standard 15 days to 30 days for the NASA planetary missions. This assessment was briefed by JSC in January 1984 at the STS/Centaur briefing to the Senior Management Panel. This precludes Shuttle turnaround in accordance with requirements to achieve a 24 flight per year launch rate. Estimates for processing of later Centaur missions reduce this OPF stay-time from 30 to 25 days because of learning. The loss of missions associated with this increased orbiter time in the OPF is estimated between one and two missions per year. Therefore, if DOD transfers two Centaur flights from the Shuttle to the commercial ELV, the potential for replacement with three or four non-Centaur flights exists. Through resale, these offer NASA the potential for increased revenue. The results of an assessment examining this potential for savings to both agencies and the Government are presented in Figures AIV-6 and AIV-7 (two flight gain) and Figures AIV-8 and AIV-9 (one flight gain). These comparisons were made

APPENDIX

against the 24 flight model. The Air Force experiences a savings of $307 million then year dollars, and the Government experiences a savings of $987 million then year dollars, when the Air Force deletes two Shuttle Centaur flights and NASA resells four flights. When the Air Force deletes two Shuttle flights and NASA resells three Shuttle flights, the Air Force experiences a savings of $232 million then year dollars, and the Government experiences a savings of $587 million then year dollars. In these comparisons, only the incremental cost savings are presented. Consistent with all comparison analyses herein, the cost of the additional Shuttle flight(s) is not included.

10 FEBRUARY 1984

AIR FORCE IMPACTS - T34D$_7$
(TWO FLIGHT GAIN)
(FULL-COST-RECOVERY MILLIONS OF TY DOLLARS)

FY	85	86	87	88	89	90	91	92	93	TOTAL
2 ORB/YR				-355	-380	-405	-435	-465		-2040
OPT SERV				-8	-9	-9	-10	-11		-47
2 ELV/YR				350	375	395	420	440		+1980
3 PROG DUAL INTEG (LV)	3	5	8	13	9	2				+40
7 SAT REC INTEG (LV)					-3	-9	-13	-14	-8	-47
P/L IMPACT	10	15	13	11	5					+54
SECURITY SAVINGS					-16	-17	-17	-18	-19	-87
STS IMPACT COST	0	0	0	-45	-20	-40	-25	-30		-160
TOTAL	+13	+20	+21	-34	-39	-83	-80	-98	-27	-307

ASSUMPTIONS:
- ELV DEVELOPMENT AMORTIZED OVER 10 VEHICLES
- AF FLIES 2 ELVs/YR

NOTE: MINUS (-) INDICATES SAVINGS.

FIGURE AIV-6

USER COST IMPACTS - $T34D_7$ 10 FEBRUARY 1984
(TWO FLIGHT GAIN)
(FULL COST RECOVERY - MILLIONS OF TY DOLLARS)

FY	85-87	88	89	90	91	92	93	TOTAL
4 STS FLIGHTS RESOLD								
DOD								
AF	54	-34	-39	-83	-80	-98	-27	-307
OTHER	0	-50	-45	-5	-45	-45	0	-190
NASA	0	-60	-85	-120	-110	-115	0	-490
GOV'T TOTAL	54	-144	-169	-208	-235	-258	-27	-987
COMM/FOREIGN	0	-65	-70	-70	-85	-90	0	-380

NOTE: ORBITER AMORTIZATION WOULD RESULT IN AN ADDITIONAL 20 MILLION DOLLAR SAVINGS PER FLIGHT NOT SOLD.
MINUS (-) INDICATES SAVINGS.

FIGURE AIV-7

10 FEBRUARY 1984

AIR FORCE IMPACTS - $T34D_7$
(ONE FLIGHT GAIN)
(FULL-COST-RECOVERY MILLIONS OF TY DOLLARS)

FY	85	86	87	88	89	90	91	92	93	TOTAL
2 ORB/YR				-355	-380	-405	-435	-465		-2040
OPT SERV				-8	-9	-9	-10	-11		-47
2 ELV/YR				350	375	395	420	440		+1980
3 PROG DUAL INTEG (LV)	3	5	8	13	9	2				+40
7 SAT REC INTEG (LV)					-3	-9	-13	-14	-8	-47
P/L IMPACT	10	15	13	11	5					+54
SECURITY SAVINGS					-16	-17	-17	-18	-19	-87
STS IMPACT COST	0	0	0	-25	-10	-20	-15	-15	0	-85
TOTAL	+13	+20	+21	-14	-29	-63	-70	-83	-27	-232

ASSUMPTIONS:
- ELV DEVELOPMENT AMORTIZED OVER 10 VEHICLES
- AF FLIES 2 ELVs/YR

NOTE: MINUS (-) INDICATES SAVINGS.

FIGURE AIV-8

USER COST IMPACTS - $T34D_7$ (ONE FLIGHT GAIN) (FULL COST RECOVERY - MILLIONS OF TY DOLLARS)

10 FEBRUARY 1984

FY	85-87	88	89	90	91	92	93	TOTAL
3 STS FLIGHTS RESOLD								
DOD								
AF	54	-14	-29	-63	-70	-83	-27	-232
OTHER	0	-25	-25	-5	-20	-25	0	-100
NASA	0	-30	-45	-65	-55	-60	0	-255
GOV'T TOTAL	54	-69	-99	-133	-145	-168	-27	-587
COMM/FOREIGN	0	-30	-30	-35	-35	-40	0	-170

NOTE: ORBITER AMORTIZATION WOULD RESULT IN AN ADDITIONAL 20 MILLION DOLLAR SAVINGS PER FLIGHT NOT SOLD.
MINUS (-) INDICATES SAVINGS.

FIGURE AIV-9

APPENDIX

TRAFFIC MODEL

YEARLY TRAFFIC 1)	89	90	91	92	93	TOTAL
AFSC						
KSC	6	3-2/3	5-1/3	3-2/3	3-2/3	22-1/3
VAFB	1	1	1	1	1	5
SUBTOTAL	7	4-2/3	6-1/3	4-2/3	4-2/3	27-1/3
DOD OTHER						
KSC	4	2	0	2	2	10
VAFB	2	4	1	3	3	13
SUBTOTAL	6	6	1	5	5	23
NASA						
KSC	5	7-1/3	10-2/3	8-1/3	8-1/3	39-2/3
VAFB	0	0	0	0	0	0
SUBTOTAL	5	7-1/3	10-2/3	8-1/3	8-1/3	39-2/3
COMMERCIAL						
KSC	6	6	6	6	6	30
VAFB	0	0	0	0	0	0
SUBTOTAL	6	6	6	6	6	30
TOTAL	24	24	24	24	24	120

Note: 1) FY 86 POM TRAFFIC (EXTRAPOLATED TO FY 93)

Figure AIV-10

APPENDIX

V. LAUNCH BASE PROCESSING

A. Titan $34D_7$

1. Requirements

The launch base provides the facilities for receipt, storage, processing, servicing, and physical support of the launch vehicle at the launch pad. For the $T34D_7$ segment SRM vehicle these facilities include the Vertical Integration Building (VIB), Solid Motor Assembly Building (SMAB), Launch Complex-41 (LC-41), Solid Motor Processing Buildings (MIS, SRS, SAS) and Payload Fairing Processing Building (MAB). See Figure AV-1 for location of these facilities at Kennedy Space Center/Eastern Space and Missile Center (ESMC).

In addition to these facilities, administrative office space, warehousing facilities and the necessary facilities to provide launch base services will be required. All of these facilities currently exist and are in use supporting either the Titan or STS launch vehicles. Certain limited modifications to some of these facilities will be required to accommodate the increased length of the booster and larger diameter of the payload fairing (PLF). Also the ability to encapsulate the payload within the PLF must be provided [possibly within the Shuttle Payload Integration Facility (SPIF)].

The payload requirement for a 200 inch diameter, approximately 79 foot long PLF is new. This size PLF imposes changes to the mobile service tower platforms and payload fairing air conditioning. Space in a humidity controlled room is required for storage, inspection, and application of the insulation system to the PLF. Space in a highbay clean room is required for encapsulation of the payload into the PLF.

The launch services required will be comparable to those currently provided to the Titan Program and its associated payloads.

The commodities utilized by the improved Titan 34D system shall be provided as GFP. Assuming a launch rate of two vehicles per year, the major commodity requirements, on a per year basis, are:

N_2O_4	=	600,000 lbs.
A-50	=	300,000 lbs.
Hydrazine	=	700 lbs.
LO_2	=	120,000 lbs.
LH	=	20,000 lbs.
LHe	=	TBD
GN_2	=	480,000 MC*
LN_2	=	48 TONS

*Thousands standard cubic feet

Kennedy Space Center/Eastern Space and Missile Center (ESMC)

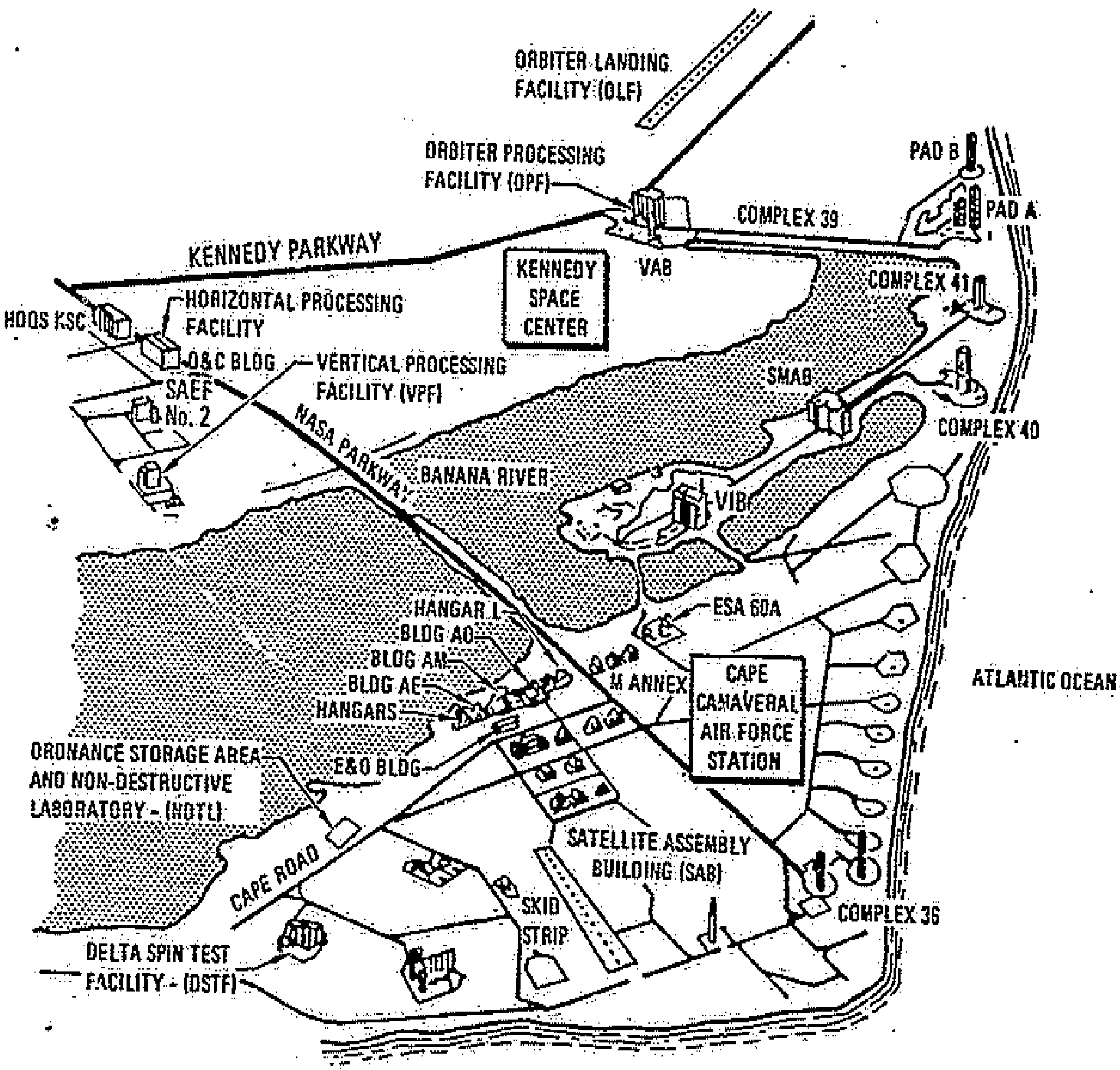

FIGURE AV-1

APPENDIX

2. <u>Implementation</u>

a. <u>Facility and Support Equipment Modifications</u>

The efforts required to install and launch the vehicle described in Section I from Launch Complex 41 can be grouped into two categories: first, the refurbishment needed to return the complex to its original operational condition, and second, the modifications necessary to convert from a Titan IIIE configuration to Titan $34D_7$ Centaur G' configuration.

The last Titan IIIE launch fr m Launch Complex 41 occured in September 1977 and the complex has received minimal maintenance since that date. The secondary structure has suffered corrosion degradation (e.g. hand rails, stairs, floor plates, hydraulic tubing, etc.); however, the primary structure remains sound. Under the category of refurbishment, the secondary structure must be repaired/replaced, elevators reworked, air conditioners reworked, electrical junction boxes and outlets replaced, etc. Cosmetically, the complex appears much worse than its true condition. The basic structure does not appear to be adversely affected by corrosion, although it will be necessary to replace the majority of the structural bolts.

It is recommended that the Architecte and Engineer (A&E) organization tasked for design of construction modifications be placed on contract as soon as possible. One of the major pacing items will be defining the condition of the Mobile Service Tower (MST) and Umbilical Tower (UT), and refurbishment effort required to return their integrity. The LC-41 MST was modified in the early 1970s for a 78 m.p.h. wind capability. Depending upon additional weight of modifications and program wind requirements, structural strengthening may be required.

After the facility has been returned to its operational capability, program peculiar modifications will be required in order to accommodate the Titan $34D_7$ segment SRM vehicle. In general, the launch vehicle is taller, heavier and boosts a larger diameter payload/PLF. The entire launch vehicle is raised on the thrust mount approximately eight feet in order to reduce ignition overpressure resulting from the longer SRMs. The MST/UT platforms must be cut out to allow the SRMs to penetrate levels 9 and 10 and permit the core vehicle to increase in length by 125 inches. A slot will be required in all platforms on the north side of the MST to permit crane access to the north SRM. The upper levels of the MST must have much larger penetration holes to accommodate a 200 inch PLF versus the previous 168 inch Centaur PLF. The added SRM weight and larger SRM nozzle diameters will require strengthening of the launch mounts.

An electrical/electronic modification is required to interface Programmable Aerospace Control Equipment (PACE) with the A2A complex wiring system. Wiring is necessary to convert from conventional AGE (i.e., Titan III configuration) to PACE (i.e., Titan 34D configuration).

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There are both mechanical and electrical modifications required to accommodate raising the ground-to-airborne interfaces. In some cases this requires relocating interface panels and boxes. In other cases, this results in extension of existing cabling and plumbing.

Much of the original Centaur AGE has been removed to support the STS program. It will be necessary to acquire new or modified Centaur AGE that is compatible with the G' configuration. One item of interest will be air conditioning units for the Centaur and payload.

Several pressurization storage tanks from the gas farms have been removed and are now used on the STS program. However, it will not be necessary to replace all these tanks because high pressure GN_2 is now available to the launch complex by pipeline installed after the Titan IIIE program facility equipment installation was built. One of the fuel Ready Storage Vessels (RSVs) on Launch Complex 41 is leaking and must be replaced. The vehicle air conditioning unit will require refurbishment. New launch heads will be required for the heavier SRMs.

Modification is required to the Environmental Shelter (ES) roof due to the increased vehicle/PLF length. Several options exist, ranging from raising the ES roof, adding a dog-house to the roof, or cutting a hole in the roof and allowing the PLF to penetrate. The proper option will be selected during the study.

Modification to the Vertical Integration Building (VIB) will be minor and will involve the Control Center and instrumentation systems. Mechanical modifications are not anticipated since this will be a stack-on-pad concept, with on-pad acceptance.

It will be necessary to provide a payload/PLF encapsulation capability. The SPIF holding cell, a SMAB SRM cell or a VIB cell could be modified for this purpose. The proper selection will be made during the study.

b. Launch Vehicle and Payload Processing

Titan $34D_7$ Stages I and II, will be transported from the skid strip at CCAFS to the lowbay of the VIB. In the lowbay, preparations will be made to transport Stages I and II to the launch complex. Preparations shall include installation of Stage I and II engines, installation of hydraulic lines and associated components, shiploose black boxes, Stage II engine nozzle extension, and Centaur interstage adapter. Each stage, in turn, will be weighed, then placed back onto the horizontal transportation device.

While preparations are proceeding in the VIB, at Launch Complex 36, the Centaur will be prepared for shipment to LC-41. All subsystem testing, including cryogenic tanking test, will be completed prior to shipment.

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Also, build-up of the seven segment solid rocket motors will begin at Launch Complex 41. The north SRM will be completely stacked. Because of the length of the seven segment solid assembly and the added length of Stage I, there is not enough distance between the crane and top of the SRM to raise Stage I into position and lower it between SRM assemblies. Therefore, only partial erection of the South SRM will be performed prior to Stage I erection.

When the SRM build-up has reached the point where Stage I is to be erected, Stage I will be transported to the launch complex, attached to a rotation fixture, rotated vertical and erected over the top of the partially built south SRM and lowered into position on the SRM attach fittings with an erection fixture similar to that now used at the Western Space and Missile Center (WSMC). Following the Stage I erection, the partial south SRM build-up will be completed and the Stage II will be transported to the launch complex and erected.

At the completion of SRM build-up, the acceptance testing will begin on the SRMs and core vehicle. The core vehicle acceptance testing will culminate with two Combined System Tests (CSTs) using SRM simulators. With SRM and core hardware acceptance completed, the electrical interfaces will be mated. Integrated subsystem, flight safety, guidance and flight control testing will be performed. Following subsystem testing, the SRM and core vehicle CST will be performed to complete lower stages readiness prior to Centaur mate.

Upon completion of the Centaur testing the aft payload fairing will be delivered to Launch Complex 36A and installed around the Centaur. The payload fairing and the Centaur will be transferred from Launch Complex 36 to Launch Complex 41 and mated to the vehicle.

Independent of booster vehicle testing, the payload will be processed in the Shuttle Payload Integration Facility (SPIF). The SPIF provides the facilities and security required to process DOD classified payloads. After check-out, the payload will be encapsulated into the upper portion of the payload fairing and the entire assembly transported to the launch complex. The NASA transporter is one method of transporting the encapsulated payload. At the launch complex, the encapsulated payload will be lifted via the 50 ton overhead bridge crane onto the booster vehicle.

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c. Payload Fairing Processing

Processing of the payload fairing will occur in a Missile Assembly Building (MAB), whereas, storage of fairing segments and hardware will occur in the Motor Inert Storage Building (MIS). The payload fairing segments will be painted/coated, and built-up into a total fairing. At this location Centaur G' snubbers, A/C ducting, umbilical penetrations, access doors, ordnance circuitry and electronic control units, thermal blankets and associated ship-loose hardware will be installed and tested. The units will be weighed, center of gravity determined, cleaned and prepared for shipment to LC-41 or the SPIF. The lower PLF segments will be installed around the Centaur and the upper segments implaced in the SPIF, assembled and the payload encapsulated. PLF transportation, handling and assembly equipment used on existing Titan III programs can be modified for the 200 inch PLF.

d. Prelaunch Integrated Vehicle Processing

Utilizing off-line testing, mating and encapsulation of the spacecraft will result in a short pad time following mating of this assembly to the booster. This concept is similar to the Titan 34D/IUS philosophy.

Following mating, simple integrated booster-to-Centaur tests will be conducted. Final preparations for launch will include a launch CST, ordnance installation, battery installation and propellant loading.

3. Studies

The following studies may be needed:

a. The Titan $34D_7$ Launch Vehicle contractor has proposed on-pad build of the launch vehicle. This should be evaluated with respect to build-up and checkout of the core in the VIB and build of five segment motors in the SMAB. Capability for checkout of other vehicles is maintained with the Integrate Transfer-Launch (ITL) concept. At four launches per year or with any serious problems, VIB checkout may be required.

b. The environmental shelter will have to be raised to surround the longer payload fairing. A simpler shelter which protects the fairing but is not environmentally controlled should be considered. The type of modification required to the MST roof should also be evaluated.

c. The ignition pressure, liftoff overpressure, acoustic and thermal environment should be evaluated for impact on launch vehicle, payload, and critical support equipment.

d. The launch base documentation and reports that will be submitted to the customer should be agreed to early in the program. Documentation must be maintained on the modifications to the facility and all aspects of the launch base processing. The use of informal submittals, sketch engineering and drawings can reduce paperwork costs. The contractor should address the approach in the study phase.

APPENDIX

B. <u>Atlas II Launch Base Processing</u>

1. <u>Requirements</u>

The requirements for launch base processing of the Atlas II/ Centaur G' launch vehicle are essentially the same as for the existing Atlas vehicles except scaled up for the larger size. Facilities will be required to receive, inspect, process and store the Atlas II, Centaur G' Stage, solid motors, and payload fairing. A highbay clean room facility is required to encapsulate the payload within the PLF.

The overall requirement of the launch base facility and support equipment is to transport, assemble, checkout, service and launch the Atlas II/Centaur G' launch vehicle. The launch base being considered is Launch Complex 41 at Cape Canaveral AFS, Figure AV-1.

Launch Complex 41 has not been used for launching for a number of years and has had minimum maintenance. As such, the base facility and support equipment will require major refurbishment, modification, and replacement. Although major demolition is not envisioned, minor mods to the concrete may be required to accommodate redesigned launch mounts and the solid motors exhaust. A new launcher will be required.

The process flow for the Atlas II will be similar to that for the existing Atlas. The Atlas II vehicle will be transported to Cape Canaveral by barge. Access to existing facilities or new storage facilities for this vehicle will be required. The erection and launch of the Atlas II vehicle will be similar to the existing Atlas systems. The Atlas II vehicle (less the payload, payload fairing, Centaur G' and solids) will be transported at the launch site on a special trailer that can serve as a strong-back to maintain the vehicle in a stretched and pressurized condition. The payload will be encapsulated in the fairing and transported separately. The Centaur G' and solids will be added at the pad.

New air conditioning systems will be required for the Atlas II, Centaur G', and the payload. New liquid oxygen (cryogenic) and RP-1 fuel propellant loading systems, and checkout capability unique to the Atlas II and Centaur will have to be added.

APPENDIX

2. Implementation

a. Facility and Support Equipment Modifications

Major refurbishment will be required to the Umbilical Tower (UT) and Mobile Service Tower (MST) for an Atlas II/Centaur G' at LC-41. This pad has not been used since 1977 and its condition has deteriorated due to corrosion. Major ground structure requires inspection to establish its integrity. Items requiring repair and/or replacement are: bolted connections, platforms, stairways, handrails, elevators and the Environmental Shelter (ES). An early inspection of the MST and Umbilical Tower (UT) is essential to define their current condition and structural capability. It is necessary that the Architect and Engineering (A&E) firm which will do the design for the facility modifications be placed on contract as quickly as possible to assist in scoping refurbishment and repair tasks.

The major modifications to the MST will be to provide access to the various areas of the Atlas II, Centaur G' and PLF. Platform hole diameters will be increased, elevations changed and new platforms added. A new environmental shelter is required for the payload, Centaur G' and payload fairing. An ordnance type area is required for receipt, checkout and storage of the solid rocket motors.

The Atlas II is a new and larger launch vehicle and thus requires a large amount of new support equipment. A list of these major items includes a transporation strong-back trailer; launch mount; liquid oxygen (cryogenic) loading system; RP-1 loading system; liquid and gaseous nitrogen systems; helium system; on pad stretch and tank pressurization capability; Atlas II, Centaur G', and payload air conditioning systems; nitrogen and helium purges for Atlas II and Centaur G' after cryogenic loading; maintenance, service and checkout equipment for the liquid rocket engines; and electronic checkout equipment. Existing Centaur support equipment at LC-41 requiring refurbishment, replacement and/or modification are the liquid hydrogen, liquid oxygen, liquid helium, nitrogen, helium, loading and storage equipment and electronic checkout equipment. New and/or modified transportation, handling, and checkout equipment (from the existing solid rocket motor (SRM) programs) can be adapted for the four SRMs. The existing PLF assembly set will be modified for the larger diameter and longer PLF.

APPENDIX

b. Launch Vehicle and Payload Processing

(1) Atlas II

The Atlas II will be unloaded from the shipping barge and towed on its transporter to hanger J in the Cape Canaveral AFS industrial area. Either the NASA unloading dock near the Vehicle Assembly Building (VAB) or a dock at Port Canaveral may be used for unloading. After inspection and minor processing in hanger J, the Atlas II will be towed to LC-41. The transporter will be connected to a rotation fixture. The 50 ton MST crane will raise the Atlas II to a vertical position using the trailer frame as a strong-back. At this time the Atlas will be lifted from the rotation fixture and placed on the launch mount. The SRMs are then installed on the Atlas II thrust section while it is in its vertical position.

(2) Centaur G'

The Centaur G' proposed test flow sequence is to receive, inspect, and process the Centaur stage at LC-36. The vehicle will be erected on a stand and completely checked-out. A cryogenic propellant loading test will be performed. The Centaur G' mounted on the Atlas II interstage adapter will then be transported to LC-41 and installed on Atlas II.

(3) Payload Fairing Processing

The Atlas II/Centaur payload fairing will be received and processed at the existing payload fairing storage facility in the Missile Assembly Building (MAB). The individual sectors will be inspected and double wrapped for storage. When required, the individual sectors will be transported to the payload/Centaur G' encapsulation facility. Currently, it is planned to use the highbay transfer aisle in the Shuttle Payload Integration Facility (SPIF) for this event. The upper section of the PLF (the lower section will be installed around the Centaur G' on the pad) will be assembled in the transfer aisle. The PLF will be placed over the payload and secured to the pallet. The encapsulated payload/PLF will then be moved through the air lock and into the center high bay of the SMAB. The 305 ton highbay crane will lift the encapsulated payload onto the NASA transporter. The transporter will take the encapsulated payload to LC-41 where it will be lifted into the Environmental Shelter for mate with the previously assembled Atlas II and Centaur G'.

c. Prelaunch Integrated Vehicle Processing

Subsystem and system tests will be performed on the Atlas and SRMs using facilities at LC 41 and 36. Atlas checkout equipment at LC-36 can be modified for checkout. Electrical equipment similar to that on the Titan IIIE/Centaur Mobile Transfer Room will be used in conjunction with existing A2A lines for checkout of the Atlas II and Centaur G'.

Subsequent to Atlas II checkout; the encapsulated payload, Centaur G', and PLF are mated to the Atlas II, and a booster Combined System Test conducted.

APPENDIX

A dual propellant load test will be conducted to verify the integrity of the completely assembled vehicle systems and tanks.

After satisfactory completion of checkout tasks, the Atlas II/ Centaur launch vehicle will be ready for launch.

3. Studies

The following studies may be needed:

a. Conduct a study of the exhaust gas flow from the five liquid rocket engines (LREs) and four solid rocket engines (SRMs) on the Atlas II to determine the capability of the LC-41 exhaust duct to accept this gas flow. Determine and evaluate the impact of resulting overpressure, ignition pressure, acoustic and thermal environments on the launch vehicle, payload and critical support equipment components. Consider the effect of the proposed sequenced start of the LREs and SRMs. Define and implement corrective action where required.

b. Perform a study to determine the type of launch mount, vehicle hold-down, release mechanism and release sequence required.

c. Conduct a launch vehicle drift study to establish a launch mount configuration that is compatible with high ground winds placards.

d. Perform a study based on payload, Atlas II, Centaur and payload fairing cleanliness, humidity and air conditioning requirements to define environmental shelter requirements. This study should trade-off local environmental control at PLF access doors via tents or hoods vs. a totally controlled environmental shelter. The possible modifications required for the shelter door and roof should also be studied as a trade-off.

e. During MST modifications for the Titan IIIE/Centaur Program in early 1970's, the MST was beefed up structurally for 78 m.p.h. winds. After design modifications are identified for the Atlas II launch facility, to be consistent with program mission requirements, the new wind structural capability should be determined. If required, additional MST structural capability should be provided.

f. The launch base documentation and reports that will be submitted to the customer should be agreed to early in the program. Documentation must be maintained on the modifications to the facility and all aspects of the launch base processing. The use of informal submittals, sketch engineering and drawings can reduce paperwork costs. The contractor should address his approach to launch base documentation in the study phase.

APPENDIX

C. Shuttle Component Vehicles

Operation of the SRB-X class vehicles from NASA STS launch facilities at KSC does appear to pose some problems. Some modifications and additions (such as a payload processing facility) may be needed but existing crews should readily adapt to the needed operations. If the operation is to be a commercial enterprise, the operators being NASA for the STS, and contractor personnel, for the SRB-X there may be some difficulty in reconciling conflicts between the NASA STS use of the facilities and use by the commercial interests.

1. SRB-X Vehicle

The elements of SRB-X ground operations at KSC are shown in Figure AV-2. The payload is processed in the VPF. All vehicle elements are then assembled in the Vehicle Assembly Building (VAB) and transported to the pad. Payload access for contingencies is available on the pad. Turnaround time was estimated to be slightly less than that of Shuttle. To perform required ground operations at KSC, some facility modifications are necessary.

2. Launch Operations

Standard Solid Rocket Booster (SRB) recovery philosophy for the first stage boosters is utilized in the SRB-X class vehicles. The payload shroud or fairing is jettisoned when dynamic pressure drops to 1 PSF. Liftoff acceleration is typically 1.8 g, max first stage is 2.9 g, max second stage is 3.6 g. Maximum Q is less than 1,000 PSF.

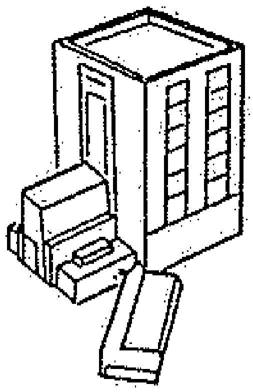
Standard STS launch control elements would be involved with the use of STS launch facilities. Necessary use of STS launch and control facilities, with their inherent levels of support overhead, appears to be a distinct economic disadvantage to the SRB-X class vehicles as compared to commercial ELVs.

Facility Modifications

- ONLY ITEMS PECULIAR TO SRB-X – NOT TO SUPPORT FLIGHT RATES GREATER THAN STS CAPABILITY

SRB-X-380

VAB



- USE HB-4
- RELOCATE ET C/O CELL
- NEW ACCESS PLATFORMS
- CRAWLERWAY EXTENSION

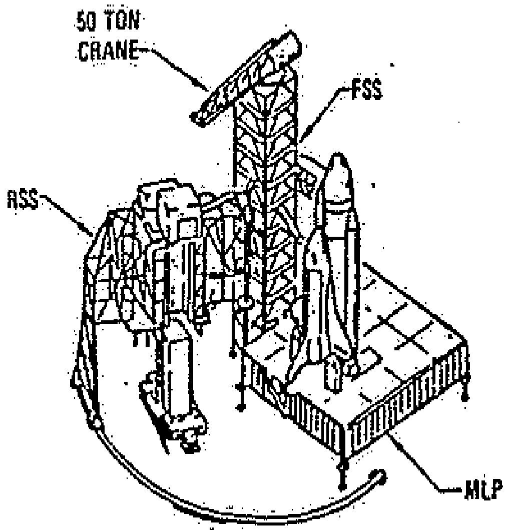
LAUNCH PROCESSING SYSTEM (LPS)

- FOR STG 2, 3, 4 AT PAD AND FIRING RM

SRB PROCESSING AND STORAGE FACIL (PSF)

- BUILD UP STANDS–STG 2
- STORAGE–STG 2

PAD 39B



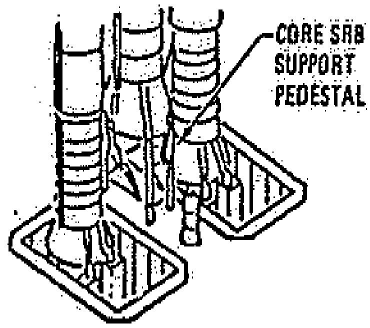
FIXED SERVICE STRUCTURE (FSS)

- REPLACE HHC WITH 50 TON CRANE
- BEEF UP FSS
- REWORK LIGHTING MAST
- ADD CRYO STAGE SERVICING AND T-0 UMBILICAL
- ADD PAYLOAD SERVICING AND T-0 UMBILICAL

ROTATING SERVICE STRUCT (RSS)

- ADD PAYLOAD ACCESS ARM
- ADD HYPERGOL UMBIL (STG 3)

MLP



MLP (modify-1, -2, or -3)

- BEEF UP COMPT 38
- T-0 UMBILICAL
- PEDESTAL FOR CORE

OPTIONAL

- NEW MLP IF >21 FLTS/YR AT KSC

FIGURE AV-2

VI. ACQUISITION STRATEGY

A. Contracting Approach

1. Risk Assessment

The tasking requires a fixed price procurement of 10 or more ELVs at two per year with first launch in FY88 or 89. The Contractor is required to finance development, production and launch services. The DOD contract will be structured to make milestone oriented payments one year prior to launch. The Contractor will recover non-recurring costs over the initial quantity of DOD launches. The DOD contract, to be awarded by 1 Oct 84, will stipulate a cancellation liability for all costs up to a predetermined ceiling incurred by the Contractor in the event the total program is cancelled and the total quantity of DOD launches is not purchased. Alternative contracting approaches are driven by risks inherent in this procurement.

a. Technical Risk

The program bears low to moderate technical risk. Viable alternatives will require design of modifications to existing hardware and will use existing design concepts to a large extent.

b. Schedule Risk

Low to moderate schedule risk is a direct result of the long term nature of this effort (9 to 11 years) and the scheduling complexities inherent in long term projections; however, such risk is assessed as manageable.

c. Cost Risk

Pricing of this effort involves cost estimates for design and development (1984-1988); cost estimating for manufacturing 10 ELV's with some undefined design characteristics (1987-1993); cost estimating for launch facility modification with exact interfaces TBD during design; and cost estimating for launch services (1987-1993). Although each of these individual efforts has a long history to serve as a foundation for cost estimates and would represent low to moderate risk, overall cost risk is increased when considered in the aggregate. Cost risk of establishing a fixed price arrangement at the outset, covering the life of the program, is considered greater from a contractual viewpoint.

2. Contract Type/Pricing Arrangement

Three alternative pricing arrangements suitable to this procurement are available under fixed price type contracts: Firm Fixed-Price (FFP); Fixed-Price Incentive, Firm Target (FPIF); and Fixed-Price Incentive, Successive Targets (FPIS). Although from a policy standpoint, FFP contracts are the preferred type, this acquisition situation leaves some question as to

its suitability because of the long period of performance and technical uncertainty. An FPIF arrangement would allow the Government the ability to incentivize the contractor to control costs and reduce the overall costs of the program to the Government. The problems of length of contract and technical uncertainty remain active in this context. An FPIS arrangement would be the most difficult to construct at the outset and requires an additional negotiation at a later point in time. This approach does, however, mitigate to some degree the problems of length of contract and technical uncertainty by allowing for adjustment of contract price at a point in time where a greater amount of cost information would be available. The only other mechanism for reducing technical and cost risk inherent in this program would be to award a Phase I contract for the initial launches followed by a Phase II contract for the remainder of the program. Any of the above approaches can be structured with appropriate performance incentives.

3. Performance Incentives for Launch Reliability

All of the alternatives in this subparagraph are based on a ROM of $200 million/launch. No consideration was given to the possibility of demanding compensation for loss of spacecraft due to launch failure.

a. Alternative 1

The Contractor would be paid a fixed amount one year prior to launch. Assuming that the first launch is the most important, there would be a significient positive performance incentive for a successful launch. Each successive successful launch (2-10) would have an increasing positive performance incentive. In addition to the performance incentive for each launch, the contractor could earn additional incentives for consecutive successful launches. The incentives for consecutive successful launches would be on an increasing scale as indicated in below.

CONSECUTIVE SUCCESSES	1	2	3	4	5	6	7	8	9	10
ADDITIVE AMOUNT/LAUNCH (Units of Performance Incentive)	1	2	3	4	5	6	7	8	9	10

An unsuccessful launch returns the scale to the first consecutive launch and eliminates the potential incentives available at the higher end of the scale.

b. Alternative 2

Alternative 2 is a simple approach to performance incentives. Based on the dollar amounts selected, this alternative can be used to establish both positive and negative incentives for the contractor. Representative amounts which could be paid to the Contractor for various success/failure scenarios are shown below.

EACH SUCCESSFUL LAUNCH	$200M
FIRST UNSUCCESSFUL LAUNCH	170M
SECOND UNSUCCESSFUL LAUNCH	150M
THIRD UNSUCCESSFUL LAUNCH	140M

The table of payments per launch could be constructed in such a fashion as to assure that the Contractor would recoup only costs for the first unsuccessful launch and the negative incentive would come into effect from that point on.

4. Alternative Acquisition Approaches/Methods

a. Contract for Supplies/Services

The requirement is to contract for launch vehicles to place spacecraft into orbit. Historically, the development, manufacturing, launch facility modification, and launch services have been contracted as separate entities. The instant acquisition requires a single contractor to establish a total price for all activity incidental to successful mission accomplishment (satellite on orbit). Treatment of this requirement on a services basis would place strong total system performance responsibility on the ELV Contractor. If a services approach is taken, careful attention will be required in establishing necessary control, documentation, and acceptance checks and balances to provide the payload agency a satisfactory level of "mission assurance".

b. Multi-Year Procurement (MYP) Versus Conventional Approach

Each of these approaches has advantages and disadvantages. This procurement could be construed to meet the criteria for MYP, although the stability of design might be open to question. This approach would allow the Contractor and Government to take advantage of economical order quantities and build rates that might not be available otherwise. MYP would require Congressional approval and waiver of the limitation imposed by the Five Year Defense Plan. The alternative is a more conventional approach with minor modifications for the peculiar situation: let a contract for the ten ELVs and allow the Contractor to approach the fulfillment of requirements in the fashion most suitable to a commercial environment. This approach would require that the Government cover the Contractor's cancellation liability should the program be cancelled because of circumstances beyond his control. The cancellation liability would be an increasing amount through the first launch and decrease after that point. The cancellaton liability would require an up front funding or a commitment from the Congress to cover the costs in the event of a cancellation.

c. Cost of Money

Interest on borrowings is not an allowable cost under the Federal Acquisition Regulation (FAR). As the Contractor will not receive payments until one (1) year prior to launch, it will be necessary for him to finance a large portion of work that would usually be covered by progress

payments or other mechanisms. A deviation from the FAR will be requested to authorize cost of money as an allowable cost.

5. Special Provision Candidates

To accomodate some of the unique features of the approach being taken to this acquisition, the contract that is awarded will require a number of special provisions.

a. Non-recurring Costs Allocated Over Government Ten Vehicle Buy

This provision would establish the Government's intention to cover all of the non-recurring costs associated with the production of commercial ELVs.

b. Downward Price Adjustment for Commercial Sales Exceeding Estimate

This provision would allow the Government to receive a price reduction for the per vehicle price should sales in the commercial area exceed the Government's estimates of potential sales. The exact mechanism will be provided for in the contract.

c. Cancellation Ceiling (MYP Approach)

Should the Government elect to award an MYP contract, there will have to be a provision for a cancellation ceiling. The cancellation ceiling would be based on the Government estimate, as modified in discussions with the offerors.

d. Cancellation Liability (Conventional Approach)

Should the Government elect to award a contract other than MYP, there will have to be a special provision that deals with the Government's liability for cancellation.

e. Government Preemptive Rights to Vehicles in Emergency

This provision would assure the Government access to commercial vehicles, developed for commercial users, in times of emergency. This provision requires a good deal of consideration of what constitutes an emergency.

f. DD 250 at Successful Spacecraft Separation

Should the Government elect to contract for the service of placing a spacecraft on orbit, there could be a special provision to DD250 the launch event at successful separation of the ELV and spacecraft.

g. No Fault Launches

A good deal of emphasis is placed on performance incentives. To protect the Contractor's rights, a special provision would need to be

developed to pay the contractor for a launch failure that was beyond his control. The amount of payment need not necessarily be the same as that for a successful launch.

h. Total System Responsibility

The ELV Contractor is expected to produce the ELV, acquire the Centaur, and assure compatibility of the full-up ELV and spacecraft through integration. Although there will be various Subcontractors and Contractors involved in this situation, the ELV Contractor must remain responsible for the placement of the spacecraft into orbit. A special provision must be written to assure this.

i. Indemnification Under Public Law 85-805

It is assumed that the potential offerors will request indemnification. It will become necessary to respond to these requests by either rapidly processing the necessary packages or by incorporating a savings provision in the awarded contract. A savings provision could be constructed that would allow for no adjustment to contract price based on either approval or disapproval of the request.

j. Commercial Use of Launch Vehicles

One of the aspects of this venture is that commercial users will be allowed to use launch facilities at the same rate as DOD users. A special provision addressing this may be required.

B. Deviations/Waivers to Facilitate Contract Plan

1. Length of Contract to Exceed Five Years

This has been discussed previously. MYP would require Congressional approval. Under the conventional approach, length of contract is not a problem.

2. Funding of Liability for Cancellation

This has been discussed previously. Congressional authority is required.

3. Amortization of Non-recurring Costs Over Government Buy

This has been discussed previously. Authority within DOD.

4. Space Division Commander's Policy on Space Parts

As this is to be commercial venture, the Contractors should be allowed the option to buy parts as necessary to meet the overall performance requirements of the vehicle. To allow the Contractor the option would require a waiver of the SD Commander's policy concerning parts to be used in spacecraft.

5. Use of Available Funds

Because this procurement has aspects of both supplies and services and because funding may come from various users, it is anticipated that various types of monies will be made available to finance the anticipated contract. As available funds may not match the type of work to be accomplished, a deviation to use funds as required to complete the contract should be granted.

6. Payments

The contract will provide for payment one year prior to launch. As the contract is structured, careful consideration will be given to establishment of specific milestones upon which payment will be based.

7. Verification of GFP/GFE/GF Fuel Base Support

The lead time to release of the request for proposal may not be sufficient to determine all items that the Government will supply or to verify the availability of such items. Because of this, it will be necessary to include some items in the RFP on a TBD basis.

8. Waiver to DODD 7200.4 "Full Funding of DOD Procurement Programs", 6 Sep '83

Authority within DOD.

C. Source Selection

1. Issues

a. Availability of Key Personnel

The necessity of making a Source Selection in FY84 requires that key personnel be available on an "ON CALL" basis to complete assigned portions of the Source Selection.

b. Delegation of Authority to Space Division Commander

The delegation of authority should be made to the Space Division Commander.

c. Audit of Offeror's Proposals

The Source Selection will take place on a compressed time schedule. In addition, unanticipated events may compress the time schedule to an even greater degree. In such an instance, it may not be possible to allow a full forty-five days for Defense Contract Audit Agency (DCAA) audit.

2. Source Selection Schedule

a. Compression of Schedule

Nominal scheduling for a Source Selection of this magnitude will not meet a contract award of 1 Oct 84. The schedule will require significant compression (Figure AVI-1). The schedule compression will require support at all levels during the various review processes.

b. Milestone Schedule

Section VII contains a top level milestone schedule developed to meet a 1 Oct 84 contract award. Normal or standard time intervals have been compressed to meet that date.

c. Business/Contract Strategy Decision Schedule

It is anticipated that the Business/Contract Strategy will be discussed in depth by Space Division, AFSC, and HQ USAF the week of 13 Feb 84 and solidified by the week of 20 Feb 84. RFP preparation will commence the week of 27 Feb 84.

ELV Contract Status Schedule

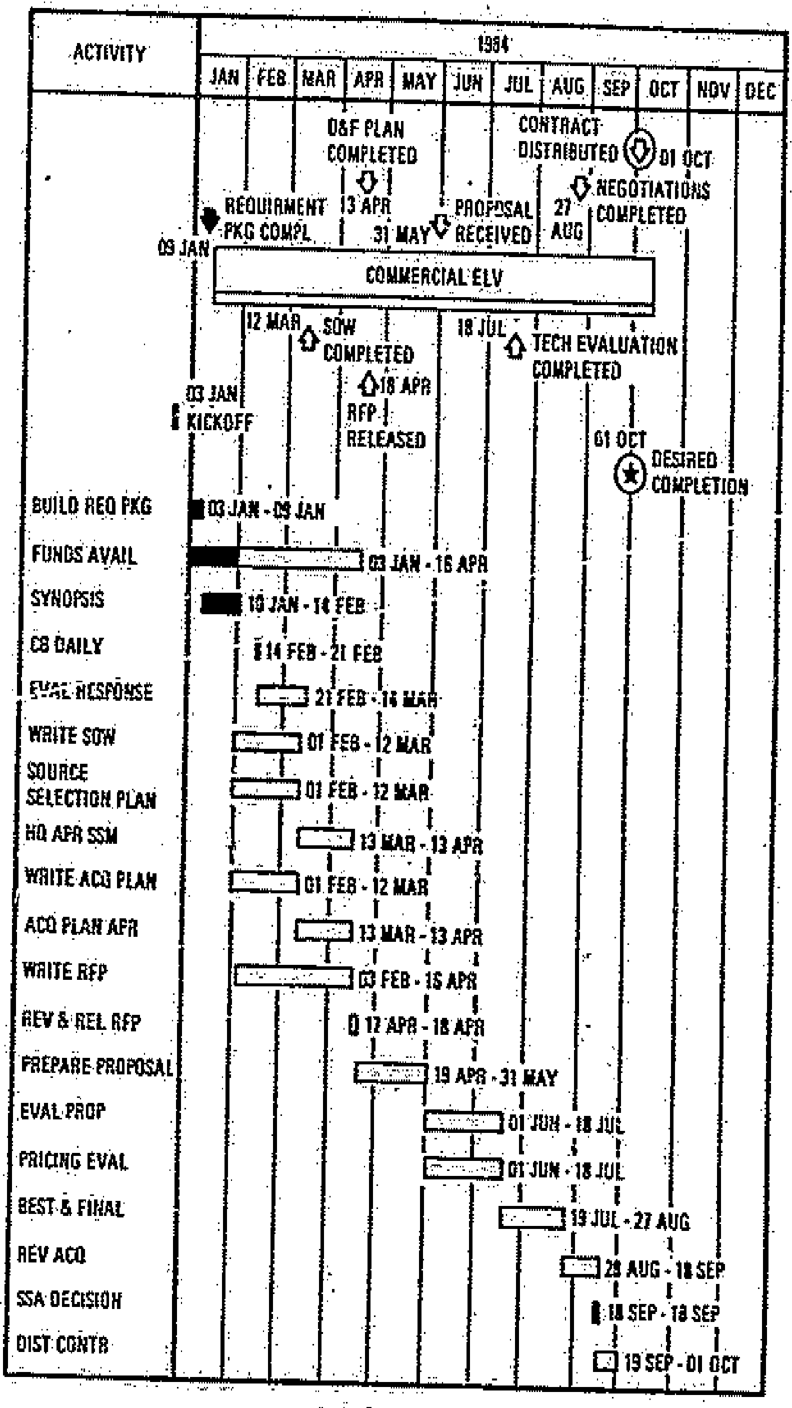


FIGURE AVI-1

VII. MILESTONE SCHEDULE

A. Titan 34D$_7$/Centaur G' Baseline Development Plan (Preliminary)

The preliminary baseline development plan, Figure AVII-1, identifies the major program milestones of System Design Review, System Preliminary Design Review, System Critical Design Review, first flight article deliveries, Centaur G' and Payload delivery to the launch complex and Initial Launch Capability. Activity duration for engineering design, manufacturing tooling, raw material procurement, fabrication, assembly, development test programs, installation of engines and avionics on the core vehicle, solid rocket motors build up, and launch operations on pad are summarized. Initial Launch Capability is 1 October 1988, with a potential improvement of eight (8) months milestones as the baseline plan.

The preliminary design/development plan, Figure AVII-2 identifies the approximate time spans for engineering design, raw material procurement for test hardware and flight hardware, fabrication and assembly of test hardware for the major contractors of core vehicle components. The development test program for the core vehicle will include structural tests for Stage I and Stage II. The payload fairing modal survey will utilize the core vehicle test code hardware and test set-up following the payload fairing separation test. The seven (7) segment solid rocket motor development will complete with two (2) static firing tests. The liquid rocket engine nonrecurring activity includes a modification to the Stage II ablative skirt to accommodate the extended burn time.

1. Titan 34D$_7$/Centaur G' Baseline Launch Operations Plan (Preliminary)

The preliminary baseline launch operations plan, Figure AVII-3, is based on the concept of installing the engines, avionics and black boxes on the core vehicle while in a horizontal position in the Vertical Integration Building (VIB). The solid rocket motors will be built up directly on the launch complex and the core vehicle will be erected between the solid rocket motors. The Centaur G', payload and payload fairing will then be added to the booster vehicle stack. All of the subsystems and flight vehicle system checkout activity will be performed while on the launch complex.

The recurring launch operations for the Titan 34D$_7$ vehicle currently planned as a 23 week activity from hardware receipt at Cape Canaveral Air Force Station to launch, with launch complex refurbishment planned as a three (3) week activity, supporting a launch rate of two (2) per year. A launch rate of four (4) per year can be accomplished by augmentation of the crew size and multiple shift work scheduling.

Titan 34D7/Centaur Baseline Development Plan

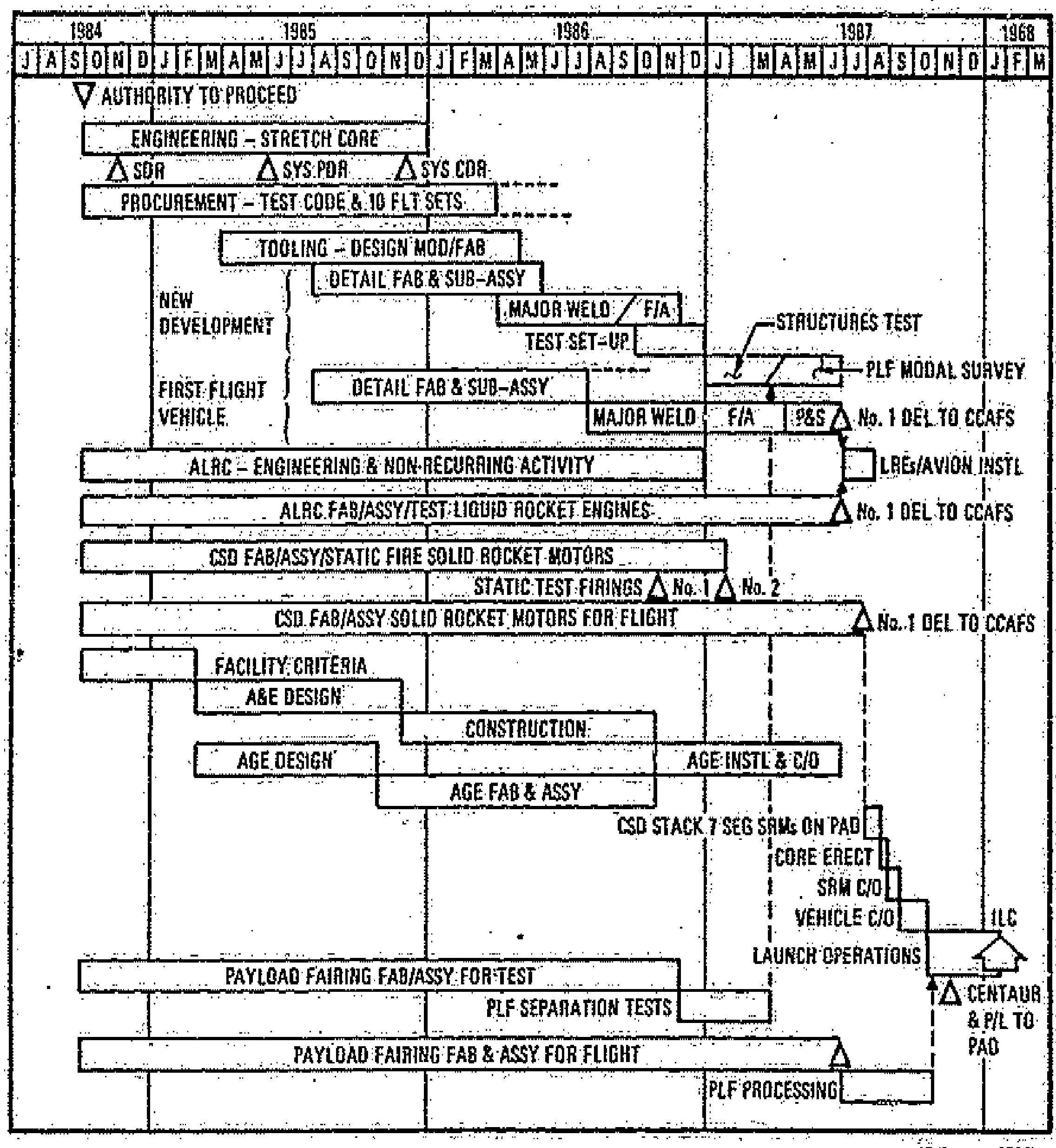


FIGURE AVII-1

Titan 34D7/Centaur Design Development Plan

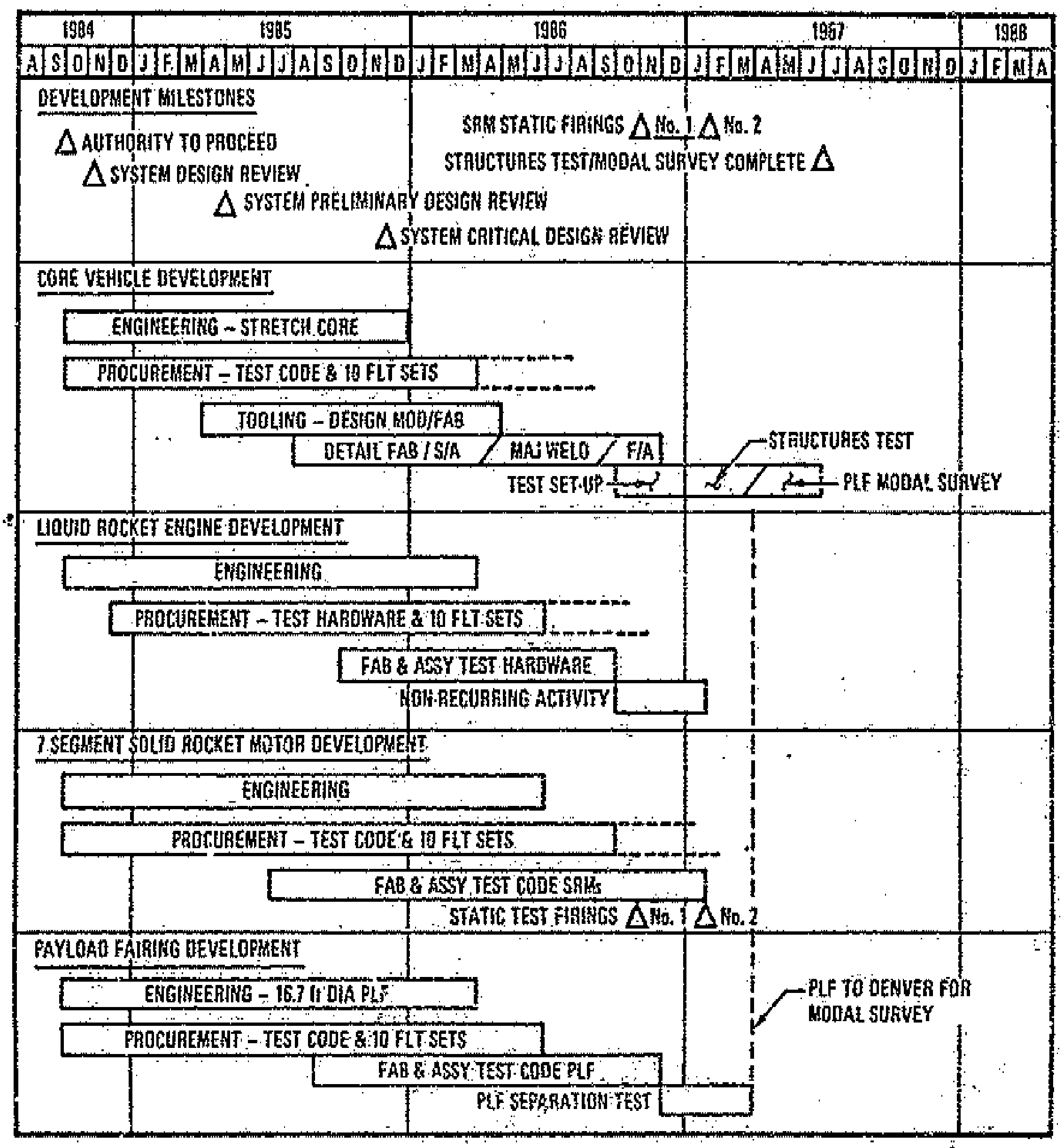


FIGURE AVII-2

Titan 34D7/Centaur Baseline Launch Operations Plan

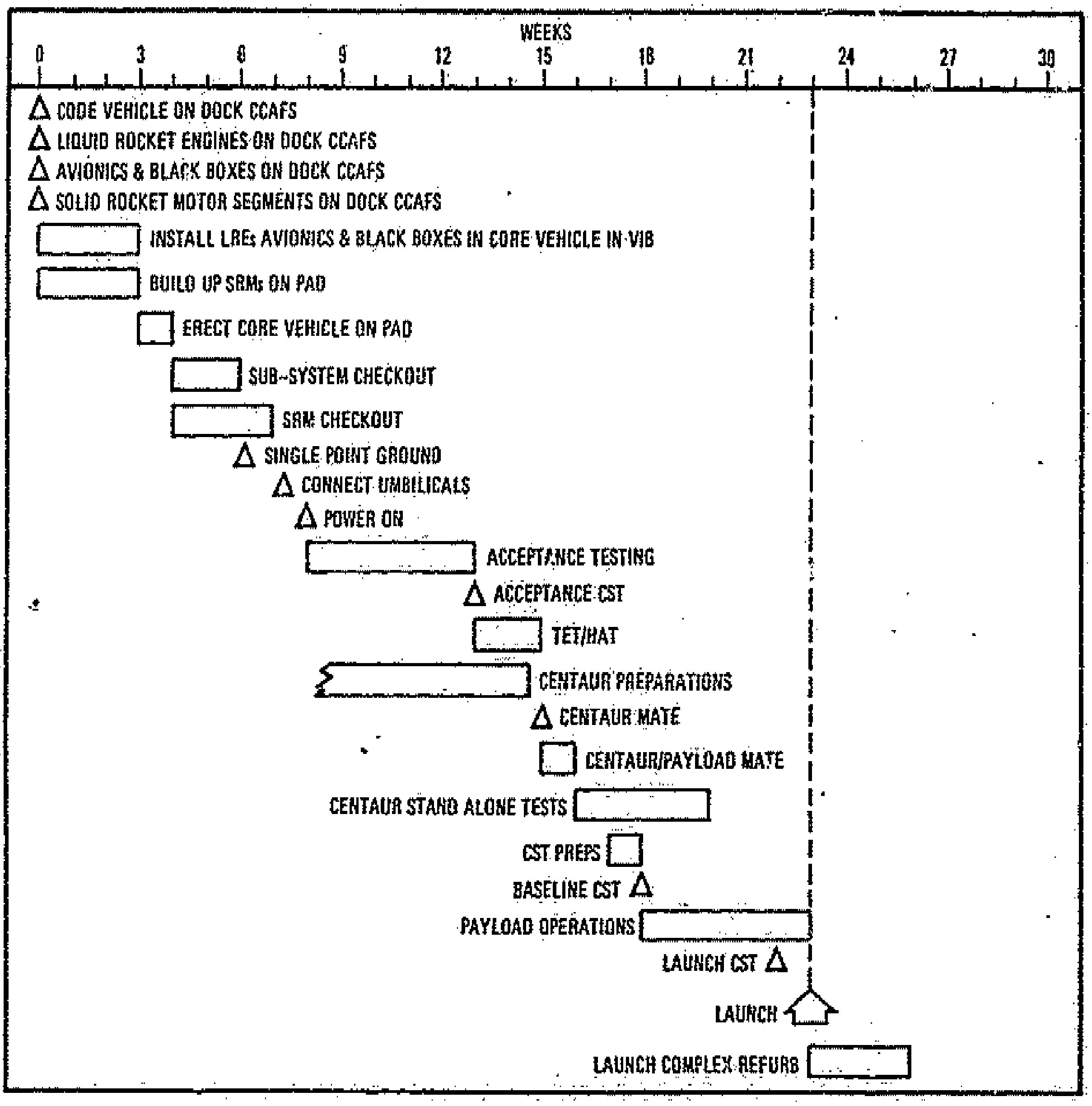


FIGURE AVII-3

B. Atlas II

The Atlas II/Centaur G' first-article schedule, Figure AVII-4, is preliminary and will be further defined as the current concept definition study progresses. Based on a program start of 1 October 1984, a first launch capability can be achieved in October 1988.

Since the Centaur G' will remain basically unchanged, the start of the design effort was delayed five months to March 1985 to avoid early manpower peaks with the Atlas II design. However, analysis and requirements effort will start in October 1984. A Centaur G' can normally be produced in 28 to 31 months, whereas the schedule allows 39 months; therefore, Centaur G' is not a pacing item.

The program has two critical paths that determine the earliest launch availability to be October 1988. The first critical path is the delivery of the H-1D engines manufactured by Rocketdyne. Based on a program start of 1 October 1984, the first set of five engines is scheduled for delivery in July 1987. These engines are required on dock one month before the start of final assembly of both the Atlas II tank and thrust structure. Based on this delivery, the earliest the Atlas II vehicle could be completed, working two shifts during final assembly, would be the end of January 1988. This supports an October 1988 launch, with one month for shipping and booster preparation at Hangar J, and seven months on stand for the first article.

If the modified Aerojet Titan III engines were to be selected in place of the Rocketdyne H-1D engines, a seven-month launch delay would result due to the 3 1/2 year delivery requirement for modifications for LO_2/RP-1 use and the requalification program.

The second critical path is design and manufacture of the Atlas thrust structure for both the test and first flight vehicles. The engineering design of the thrust structure paces the development of the numerical control tapes and the machining of the parts required to start the test article thrust structure build-up. To complete all testing by March 1988, concurrency between the test vehicle and the first flight vehicle will be required during thrust structure barrel assembly. This, in turn, will require a partial duplicate barrel holding fixture.

Test vehicle barrel assembly starts in October 1985, followed two months later by the flight vehicle. This creates a one-month overlap of the two vehicles. However, the schedule allows one month contingency between thrust structure barrel assembly and the start of final assembly. This covers any contingencies that might develop.

Early in the program, transonic wind tunnel testing will be performed. Scale models will be built to perform the test in existing AEDC test facilities. Pacing the completion of the test program is the manufacture of the test tank (stub) and thrust structure as described earlier. The first test will be the engine frequency response test using surplus engines. This test will obtain closed-loop charactertistics of booster and sustainer engine electro-hydraulic servo system. This will be followed by a limit and ultimate

Atlas II / Centaur G'

FIRST-ARTICLE MASTER SCHEDULE

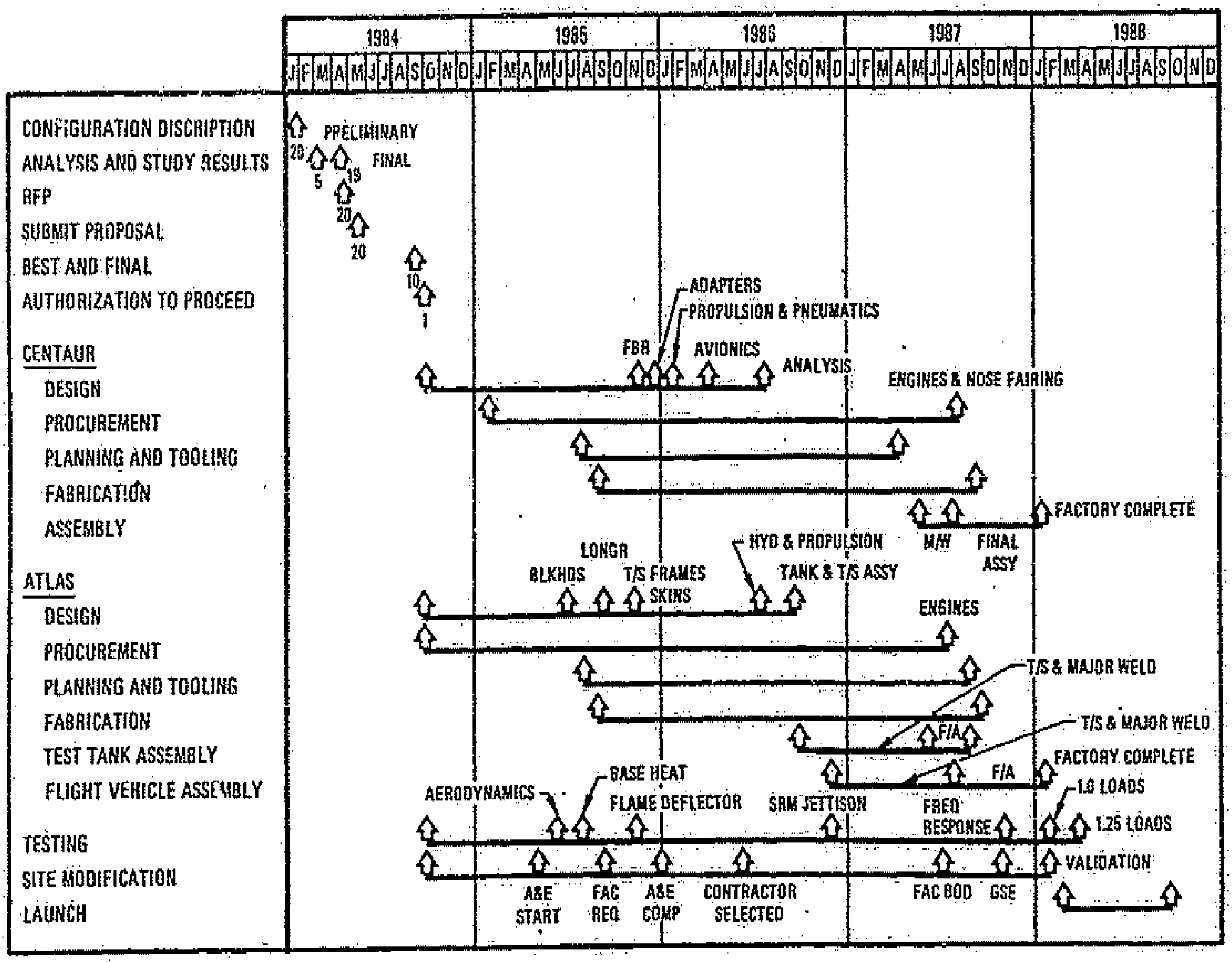


FIGURE AVII-4

load structural test. These tests will be complete in March 1988, 6 1/2 months before launch availability.

The schedule time required to design, modify, and validate the sits at ETR is less than 36 months. Therefore, the start of Ground Support Equipment (GSE) and Architect and Engineering (A & E) design was delayed three to six months, respectively, to reduce the manpower requirements during the intitial phase of the program. The site modification schedule easily supports all program requirements.

The production of the ten vehicles would be on six-month centers; however, this could be reduced to three-month centers were the launch schedule requirement to change.

The first vehicle is scheduled for seven months on stand to run the various tests and proof out the total system. After the first launch, the stand time will be reduced to approximately three months, thereby allowing flexibility in the launch requirements.

C. SRB-X

The schedule in Figure AVII-5 shows that the SRB-X concept could be developed within 54 months from ATP to first flight. This does not include time for trade studies, concept selection and competitive selection of a development contractor. This activity would add at least an additional 24 months to the schedule.

SRB-X Program Summary Schedule

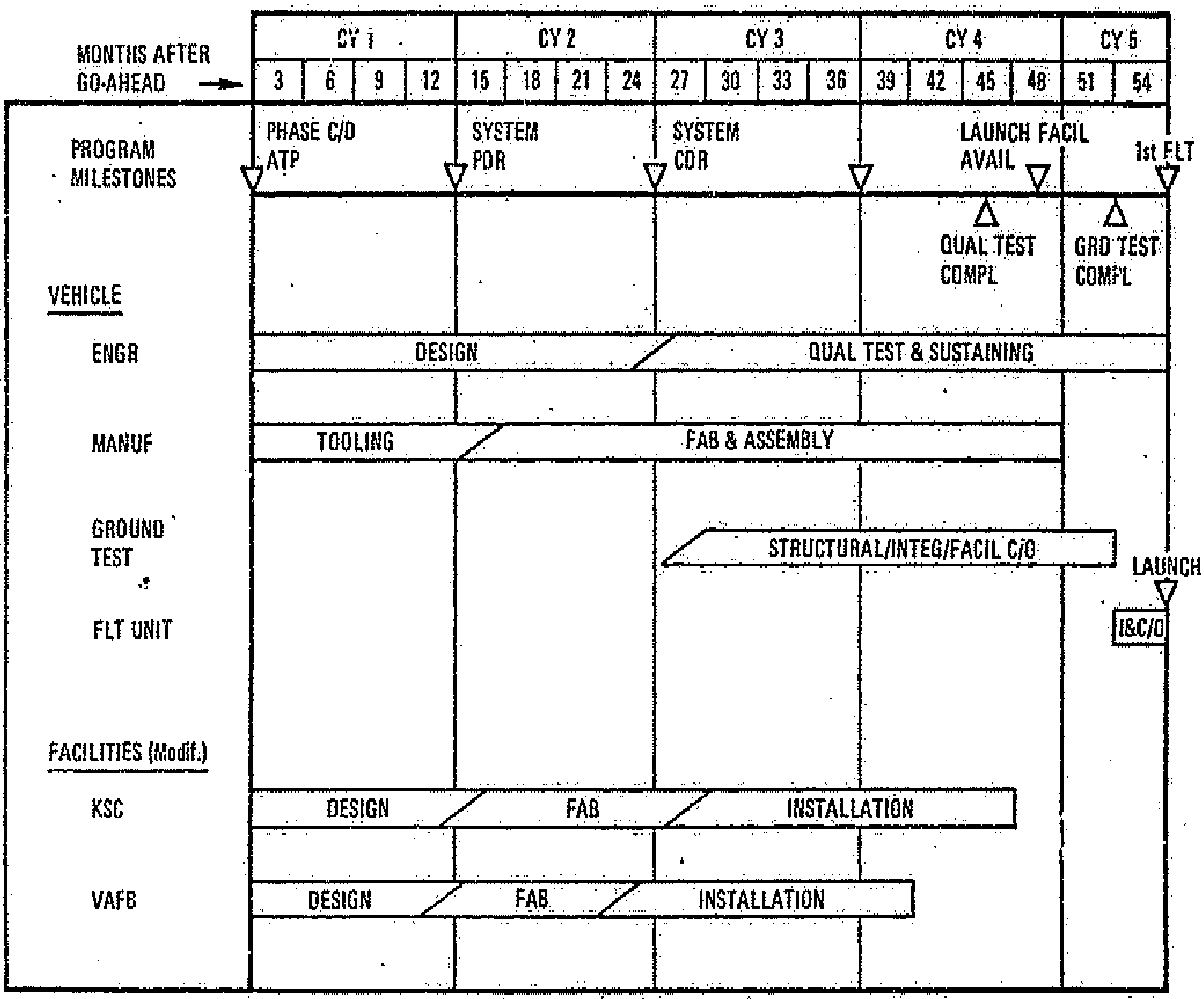


FIGURE AVII-5

COMPLEMENTARY SPACE LAUNCH STRATEGY

FOR

ASSURED ACCESS TO SPACE

SMALL PAYLOAD MISSIONS

10 FEBRUARY 1984

HEADQUARTERS SPACE DIVISION
AIR FORCE SYSTEMS COMMAND (AFSC)
United States Air Force
P.O. Box 92960, Worldway Postal Center
Los Angeles, California 90009

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TABLE OF CONTENTS

I INTRODUCTION

DOD small payloads now flying on the Atlas-E space launch vehicle are transitioning or planning transition to the Space Shuttle. These payloads include the Defense Meteorological Satellite Program (DMSP) and the NAVSTAR Global Positioning System (GPS). When the last of the Atlas-E vehicles is flown, transition of the small payloads to the Space Shuttle will be completed.

With the deactivation of the Titan II weapon system from the strategic deterrent force, a valuable national asset is becoming available as a possible space launch system for small payloads. A fleet of 56 Titan II vehicles will ultimately become available when deactivation is completed in 1987.

This study examines the technical viability, schedule, costs and risks associated with use of the Titan II and other candidate expendable launch vehicles (Atlas, Delta and MX) for small payloads. The costs of using the Titan II for launching DMSP, Navstar GPS and other DOD and civil payloads are compared to those for launching these payloads on the Space Shuttle. Results of this study indicate that use of the Titan II as a space launch vehicle is technically feasible and cost effective and that sufficient potential payloads exist to support a continuing program.

II TITAN II

A. DESCRIPTION

The Titan II ICBM is an inertially guided, silo-launched, two stage, liquid engine missile system. Two modified Titan II configurations were considered for use as space launch vehicles (Figure II-1).

1. Configuration One

The first configuration is planned for the lighter weight, low altitude orbit payloads. This configuration utilizes an 8 x 26-ft payload fairing; modifications to the instrumentation, tracking and flight safety systems; and incorporation of digital flight controls. The engines would be refurbished and hot-fire tested.

2. Configuration Two

This configuration is planned for the heaviest and highest altitude mission requirements, such as GPS. Performance is enhanced by the addition of four CASTOR IV strap-on solid rocket motors and an Improved Propulsion Space Motor (IPSM) third stage (Figure II-2). Other modifications for this configuration are very similar to those for Configuration One, except for use of a 10-ft x 30-ft payload fairing. To incorporate a 10-ft diameter skirt to support this payload fairing, it is necessary to replace the existing forward dome of the Stage II tank with a new K frame and a new dome.

Titan II Space Launch Vehicle

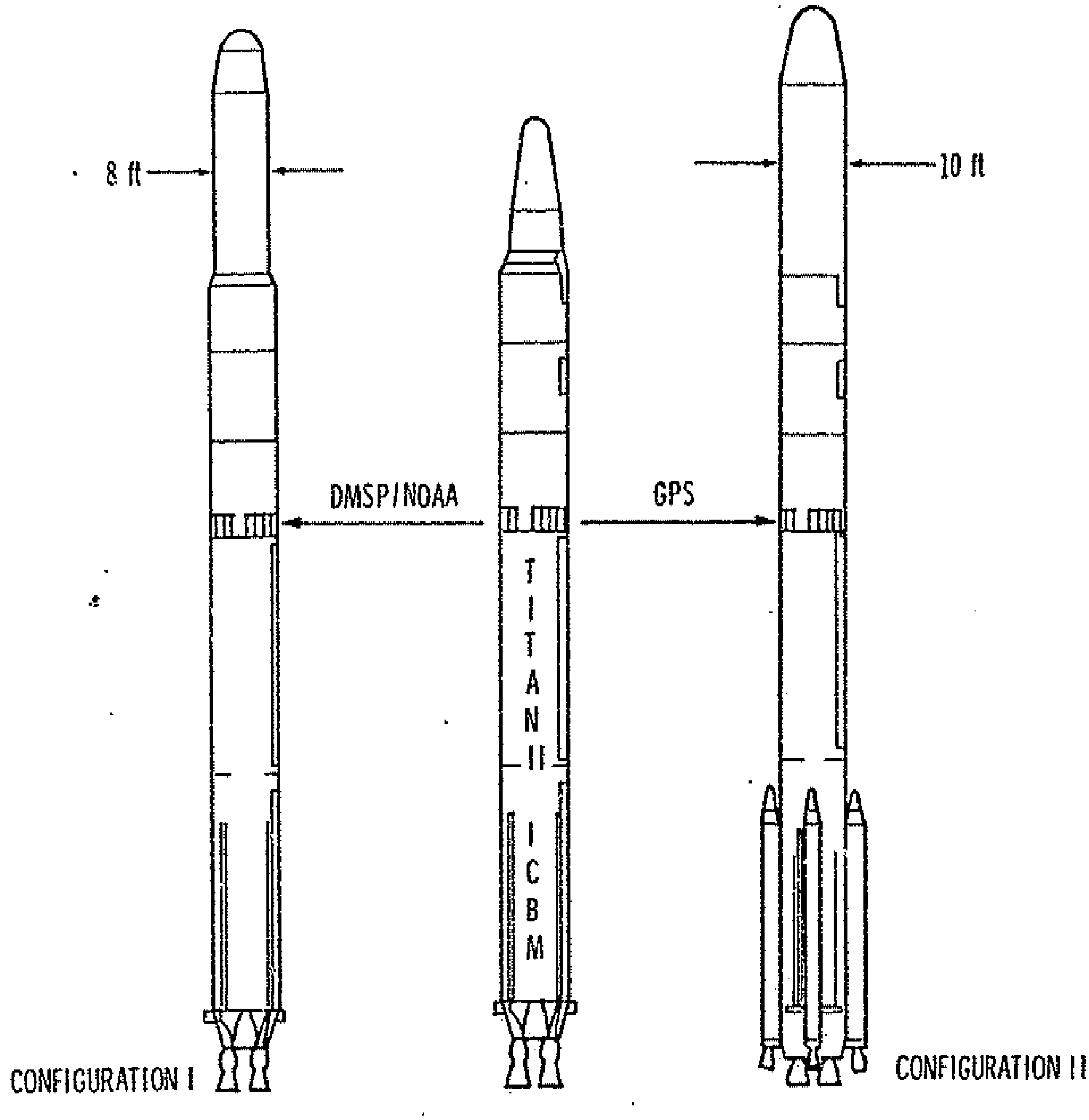

FIGURE II-1

Titan II/GPS Configuration

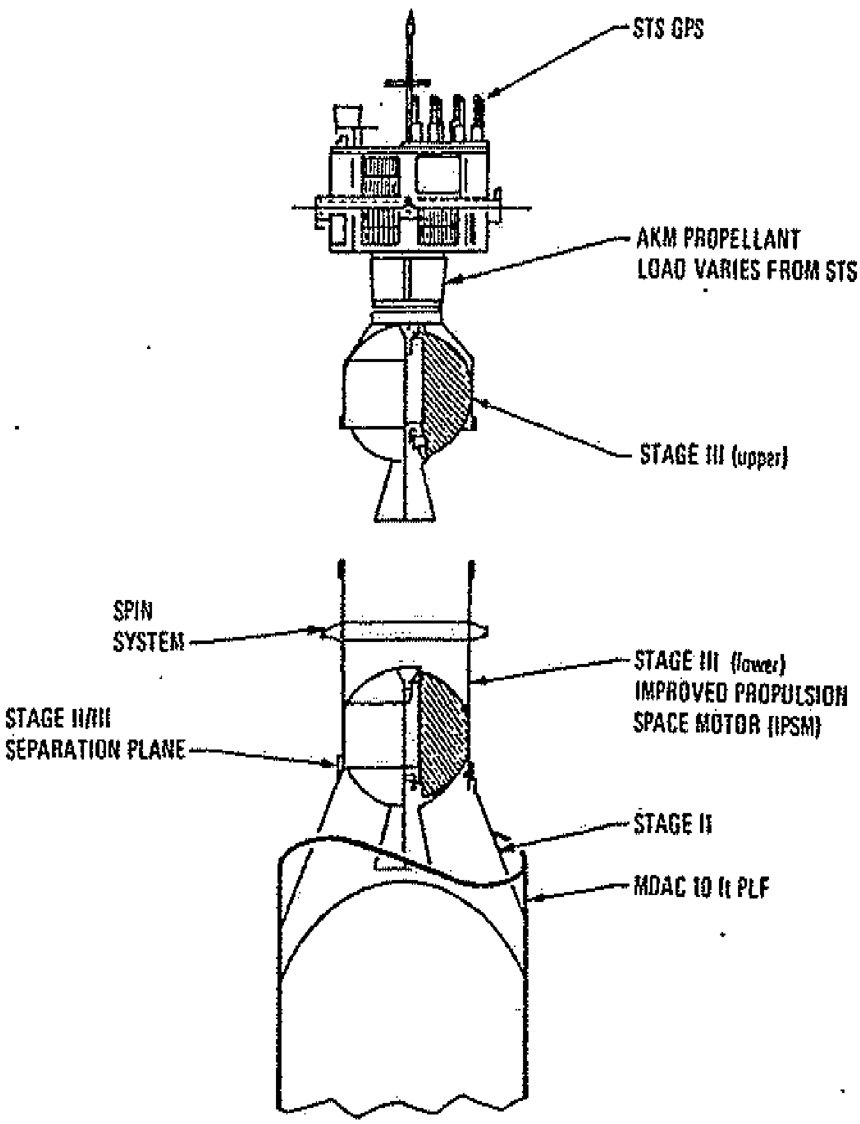

FIGURE II-2

B TITAN II PERFORMANCE

In evaluating the performance requirements of the Titan II, several candidate payloads were considered: DMSP, National Oceanic and Atmospheric Administration (NOAA), Space Test Program (STP), and GPS. Figure II-3 presents the payload requirements versus Titan II capability for each mission when launched from Vandenberg AFB (VAFB).

The Configuration One Titan II has adequate capability for both DMSP and NOAA, but is inadequate for the requirements of GPS (Block III). However, sufficient performance to boost GPS to its 10,898 nautical mile circular orbit is available from the Configuration Two Titan II with the four CASTOR IV motors and the third stage.

Titan II Space Launch Candidates

VAFB LAUNCH

PROGRAM	ORBIT (NM)/INCL	REQUIREMENT (LBS)	CAPABILITY (LBS)
TITAN II			
DMSP	450 CIRC/i = 98.7°	2284	2669
NOAA	SIMILAR TO DMSP		
STP	250 CIRC/i = 90°	<4300	4300
GPS	10,898 CIRC/i = 55°	2285	1952
TITAN II/ CASTOR IV			
GPS	10,898 CIRC/i = 55°	2285	2497

FIGURE II-3

C TITAN II SCHEDULES

Since the current DMSP and NOAA payloads are committed to Atlas launch vehicles until the fleet of Atlas-E vehicles is depleted in 1988-89, the development schedule (Figure II-4) for Configuration One Titan IIs is tailored to provide launch capability beginning in 1989. By scheduling contract go-ahead for 1 Oct 85, the launch crew continuity at VAFB can also be preserved.

The schedule for Configuration Two is based on the Block III GPS launch requirements. The associated development program would be similar to that of Configuration One with contract go-ahead in mid-1988 and launch capability by January 1991. A decision would be required earlier, however, for the GPS spacecraft to support development and procurement of the Block III spacecraft.

The proposed launch model for the Titan II space launch vehicle is shown in Figure II-5. Based on this launch model, a launch rate of 6 per year was baselined.

Titan II Conversion to Space Launch Vehicle

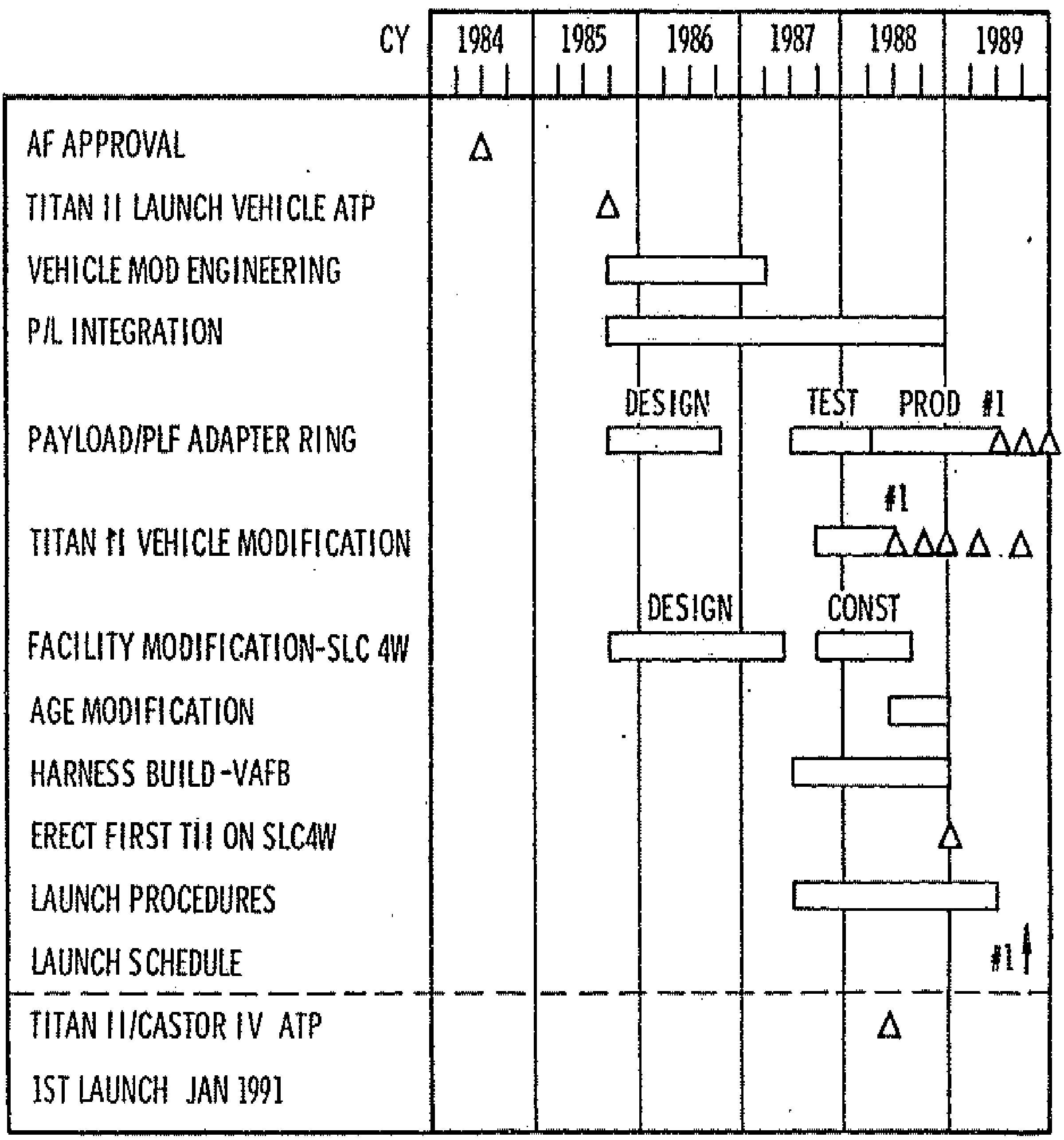

FIGURE II-4

Titan II Mission Model

	FISCAL YEAR					
	89	90	91	92	93	94
PROGRAMS						
TITAN II						
DMSP		1	1	1	1	1
NOAA	1	1	1	1	1	1
STP*		2	1	1		
	1	4	3	3	2	2
		5	8	11	13	15
TITAN II/CASTOR IV						
GPS			4	4	4	4
				8	12	16
			12	19	25	31

*NOT FIRM MISSIONS

FIGURE II-5

D TITAN II TECHNICAL RISK

From a technical standpoint, the fact that all of the required modifications to the Titan II for Configuration One employ existing Titan III technology and hardware makes this program low risk. In addition, the on-going Titan II ICBM Service Life Analysis Program (SLAP) and Reliability, Aging, and Surveillance Program (RASP) results indicate that a very low fall-out of Titan II hardware is expected in the refurbishment and reacceptance program.

Since Configuration Two requires incorporation of an upper stage and the CASTOR IV strap-ons, a 30-month schedule would seem to present some risk. However, it should be recognized that the new stage incorporates a totally developed and tested motor and that the CASTOR IV motors are off-the-shelf equipment requiring no modification. Existing studies and experience on incorporating strap-on solids on the Titan III configuration contributes to minimizing this concern. It should be noted that the upper stage consists basically of a solid rocket motor and a propulsive spin system adapted from an existing stage, which should present no development or production problems.

The higher thrust and heavier payload on Configuration Two will require additional analyses and testing. It is also apparent that the structural design will need to be stiffened and/or strengthened in the areas of the tank bottom and CASTOR IV attachment. Structural testing will be required to ensure flight reliability of the modified structure.

Based on the above considerations, the technical risk for Configuration Two is assessed as low.

E TITAN II COSTS

This section identifies the cost impacts of utilizing Titan II for DMSP, NOAA, STP, and GPS. Costs impacts to DOD, all U. S. Government, and all Shuttle users are presented in Figures II-6, II-7 and II-8, respectively. The cost impact to DOD of use of Titan II to launch DMSP, STP and GPS through 1994 is a potential net savings of over $600 million then year dollars for the baseline case in which NASA is able to resell all GPS Shuttle launch slots. To effect these savings, near term monies are required. The potential impact to all U.S. Government users, including DOD, is a savings of approximately $800 million then year dollars for the baseline case. Figure II-8 shows the potential impact to all Shuttle users.

1. The impact elements in Figures II-6 thru II-8 are:

a. Titan II Costs

The costs for Titan II include non-recurring development, recurring hardware procurement/modifications, launch pad modifications, payload integration and launch operations for both Configuration One and Two. These costs reflect a 31 vehicle flight program through 1994.

b. Shuttle Flight Charge Savings

The savings through use of Titan II launches are realized in the year prior to launch. The Shuttle full-cost recovery flight charge estimate was derived from the latest available NASA data in POP 83-2, dated Aug 83.

c. Payload Design Savings

These savings result from deleting the need to design dual ELV/Shuttle compatible spacecraft as presently planned. DMSP and NOAA could continue to procure the same basic spacecraft as now flies on Atlas-E. Savings in Figures II-6 and II-7 reflect amounts currently in approved budgets.

IMPACT TO DOD
GPS RESOLD
THEN YEAR M $

FY	86	87	88	89	90	91	92	93	94	TOTAL
TITAN II COSTS	50.9	77.5	116.7	150.5	166.1	242.3	276.4	131.6	129.8	1341.8
SHUTTLE FLT CHG SAVINGS*				-277.2	-419.3	-449.2	-481.0	-515.2		-2141.9
PAYLOAD DESIGN SAVINGS (DMSP)	-4.5	-40.4	-23.8	-11.3						-80.0
STS IMPACT COST (DOD)*			19.2	70.2	30.2	46.6	49.9	53.4		269.5
DOD TOTAL IMPACT	46.4	37.1	112.1	-67.8	-223.0	-160.3	-154.7	-330.2	129.8	-610.6

NOTE: (-) INDICATES SAVINGS

*ASSUMES FULL COST RECOVERY FOR SHUTTLE IN THE RATIO OF SHUTTLE FLT CHARGES PER PAYLOAD SHOWN BELOW

DMSP=1
GPS=.33
STP=.5
NOAA=.5

FIGURE II-6

IMPACT TO U.S. GOVERNMENT

GPS RESOLD

THEN YR M $

FY	86	87	88	89	90	91	92	93	94	TOTAL
STS IMPACT COST (NASA)			8.8	74.7	63.3	55.6	59.7	63.8		325.9
NOAA SHUTTLE FLT CHG SAVINGS			-64.7	-69.3	-74.3	-79.5	-85.2	-91.2		-464.2
PAYLOAD DESIGN SAVINGS (NOAA)	-2.8	-25.3	-14.9	-7.0						-50.0
DOD TOTAL IMPACT*	46.4	37.1	112.1	-67.8	-223.0	-160.3	-154.7	-330.2	129.8	-610.6
GOVT TOTAL IMPACT	43.6	11.8	41.3	-69.4	-234.0	-184.2	-180.2	-357.6	129.8	-798.9

NOTE: (-) INDICATES SAVINGS

*ASSUMES FULL COST RECOVERY FOR SHUTTLE IN THE RATIO OF SHUTTLE CHARGES PER PAYLOAD SHOWN BELOW

DMSP=1
GPS=.33
STP=.5
NOAA=.5

FIGURE II-7

IMPACT TO ALL USERS
GPS RESOLD
THEN YEAR M $

FY	86	87	88	89	90	91	92	93	94	TOTAL
GOVT TOTAL IMPACT	43.6	11.0	41.3	-69.4	-234.0	-184.2	-180.2	-357.6	129.8	-798.9
STS IMPACT (COMM & FOREIGN)			9.6	54.9	34.0	36.4	39.0	41.7		215.6

NOTE: (-) INDICATES SAVINGS

*ASSUMES FULL COST RECOVERY FOR SHUTTLE IN THE RATIO OF SHUTTLE FLT CHARGES PER PAYLOAD SHOWN BELOW

DMSP=1
GPS=.33
STP=.5
NOAA=.5

FIGURE II-8

d. STS Impact Cost

The STS operations costs are comprised of both fixed and variable costs. When the STS flight model is reduced, the cost per flight of the remaining Shuttle flights will increase to offset the pro-rata portion of fixed costs apportioned to the deleted flights. As it is highly likely that the deleted GPS Shuttle flights will be resold, since they are PAM-D II missions, the baseline case used in this study assumed GPS Shuttle flights at KSC are resold but deleted VAFB Shuttle flights (e.g., DMSP) are not.

2. Titan II Cost Risk Assessment

Costs were examined for both completeness and reasonableness and include both Shuttle and ELV cost considerations. The Titan II cost risk assessment addresses the risk for total program growth.

Modifications proposed for Titan II are similar to efforts completed in the past on both the Titan III program and the Atlas overhaul program. This similarity provides confidence in both the technical and cost risk assessments. The contractor estimates for nonrecurring and recurring costs were reviewed and adjusted to include elements of cost known to have been omitted and to protect against unknowns. Based upon the above, costs are believed to be complete and reasonable.

3. Shuttle Impact

The scenarios relating to the impact to DOD and the impact to other Shuttle users are affected by the Shuttle cost per flight assumed in the 1990-1994 time period. For purposes of this study, a flight charge of $133 million in FY83 dollars was used for KSC flights as discussed in paragraph E.1.b.

Although not included in this analysis, there exists an additional potential cost savings resulting from the cost amortization of eventual replacement orbiters. The orbiter amortization cost savings can be calculated based upon a $2 billion cost for a replacement orbiter divided by an assumed life of 100 flights for a value of $20 million per Shuttle flight not required to fly Titan II payloads.

III ATLAS

The candidate Atlas vehicles to support DMSP and GPS class payloads are the Atlas H and a stretched Atlas K. For the DMSP mission, the current Atlas H easily satisfies the performance requirement.

To meet GPS performance, an Atlas K with additional tank stretch would be required. The Atlas K is the Atlas H with Atlas E avionics and a tank stretch of 183 inches. Figure III-1 depicts the Atlas H and Atlas K vehicles, and Figure III-2 presents the performance capability of each.

Atlas Launch Vehicles

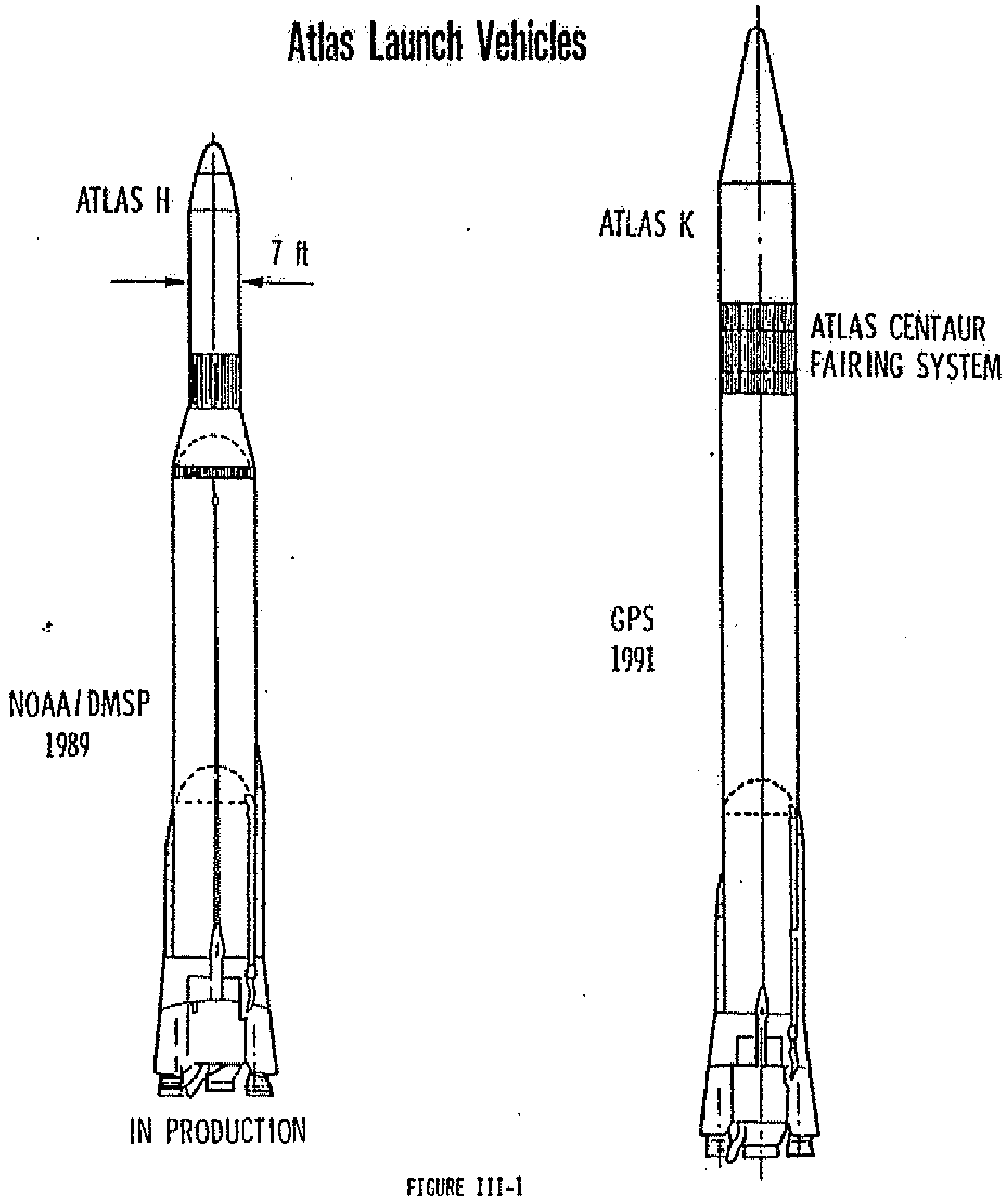

FIGURE III-1

Military Uses of Space: 1946-1991

Published by:
Chadwyck-Healey Inc., 1101 King Street, Alexandria, Virginia 22314

Military Uses of Space: 1946-1991 provides a detailed record of the strategic importance of the U.S. military space program from the conceptualization of the uses of space to the present realization of advanced capabilities. Materials were identified, obtained, assembled, and indexed by the National Security Archive, a non-profit, Washington, D.C. based research institute and library. The microfiche collection is accompanied by Military Uses of Space: 1946-1991 Guide and Index.

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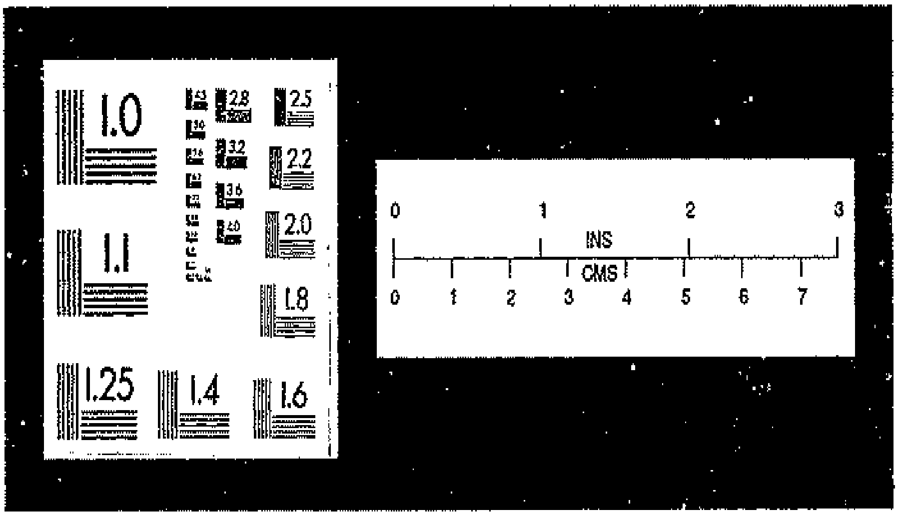

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Atlas

PERFORMANCE CAPABILITY
VAFB LAUNCH

ORBIT (NM)	VEHICLE	REQUIREMENT (LB)	CAPABILITY (LB)
450 CIRC	ATLAS H	2284	3000
10898 CIRC	ATLAS K*	2285	2180

*ATLAS H TANK STRETCHED 183"

(FURTHER STRETCH REQUIRED TO MEET GPS PERFORMANCE REQUIREMENT)

FIGURE III-2

IV DELTA

The candidate Delta launch vehicles for the DMSP and GPS class payloads are the Delta 3310 and a higher performing Delta 4920A/PAM (Figure IV-1). The Delta 3310 is capable of directly injecting the DMSP/NOAA payload into the final mission orbit. The GPS mission requires development of a growth Delta, the 4920A/PAM, with 9 CASTOR IVA motors, a 12-ft tank stretch, and a large payload fairing. The performance data for the Delta vehicles are shown in Figure IV-2.

Delta Launch Vehicles

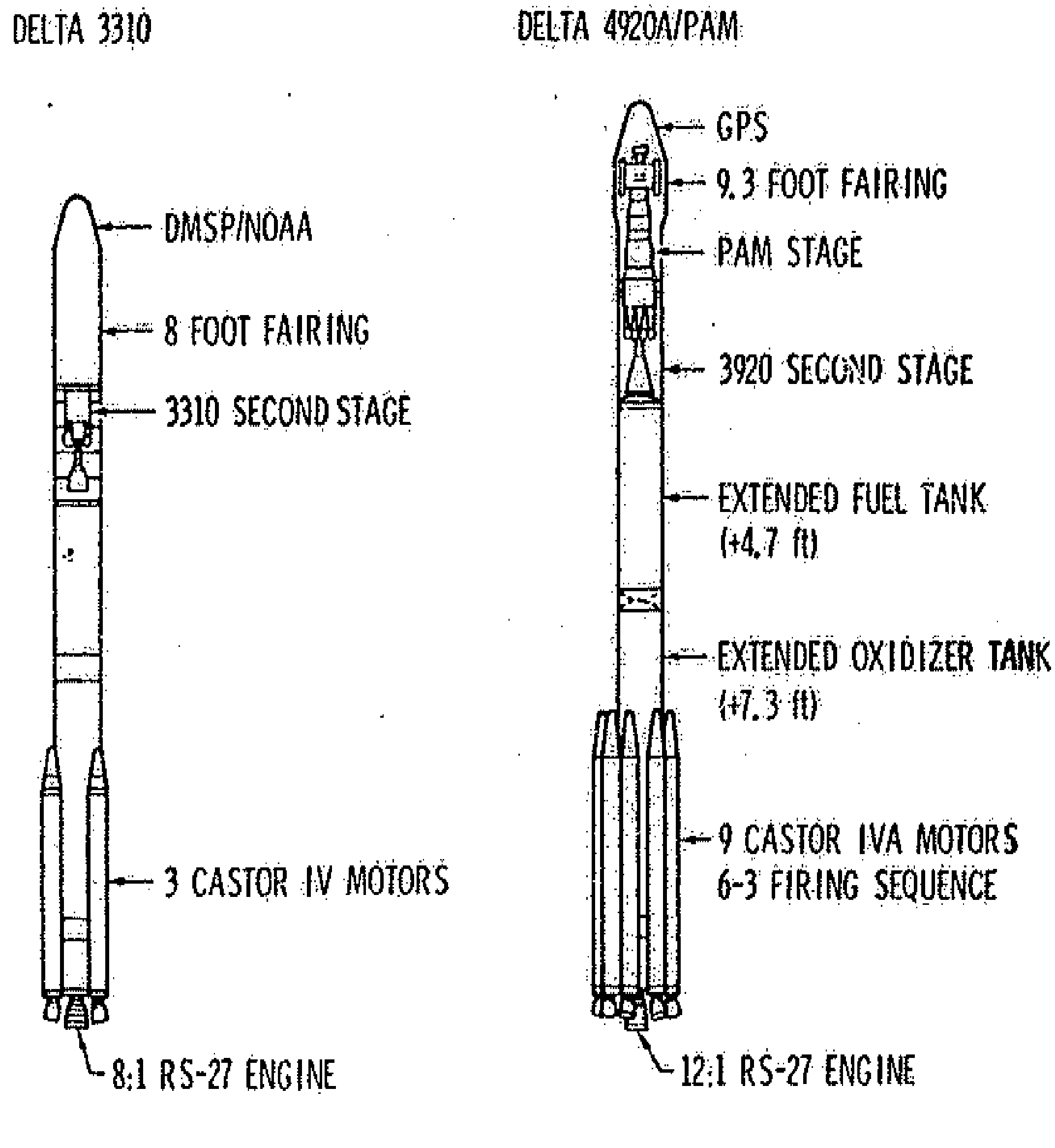


FIGURE IV-1

Delta Performance Capability

VAFB LAUNCH

ORBIT (NM)	VEHICLE	REQUIRMENT (LB)	CAPABILITY (LB)
450 CIRC	3310	2113*	2200**
10898 CIRC	4920A/PAM***	2285	2390

* S/C AKM AND N_2H_4 SYSTEM NOT REQUIRED

** WITH S/C BOOST GUIDANCE 80 LB INCREASED PERFORMANCE

*** DELTA WITH TANK STRETCHED - 12 FT

FIGURE IV-2

V MX

The basic studies done in the past considered the present MX nose geometry constraint in both diameter and length (Figure V-1). None of the current military spacecraft can be contained within the MX nose cone. From a pure performance standpoint, the MX can deliver the current DMSP/NOAA weight to the proper orbit. Further analyses are planned to develop the recurring modification, engineering, and hardware costs and schedule for conversion of the MX to a space launch vehicle.

MX Booster Space Launcher Application

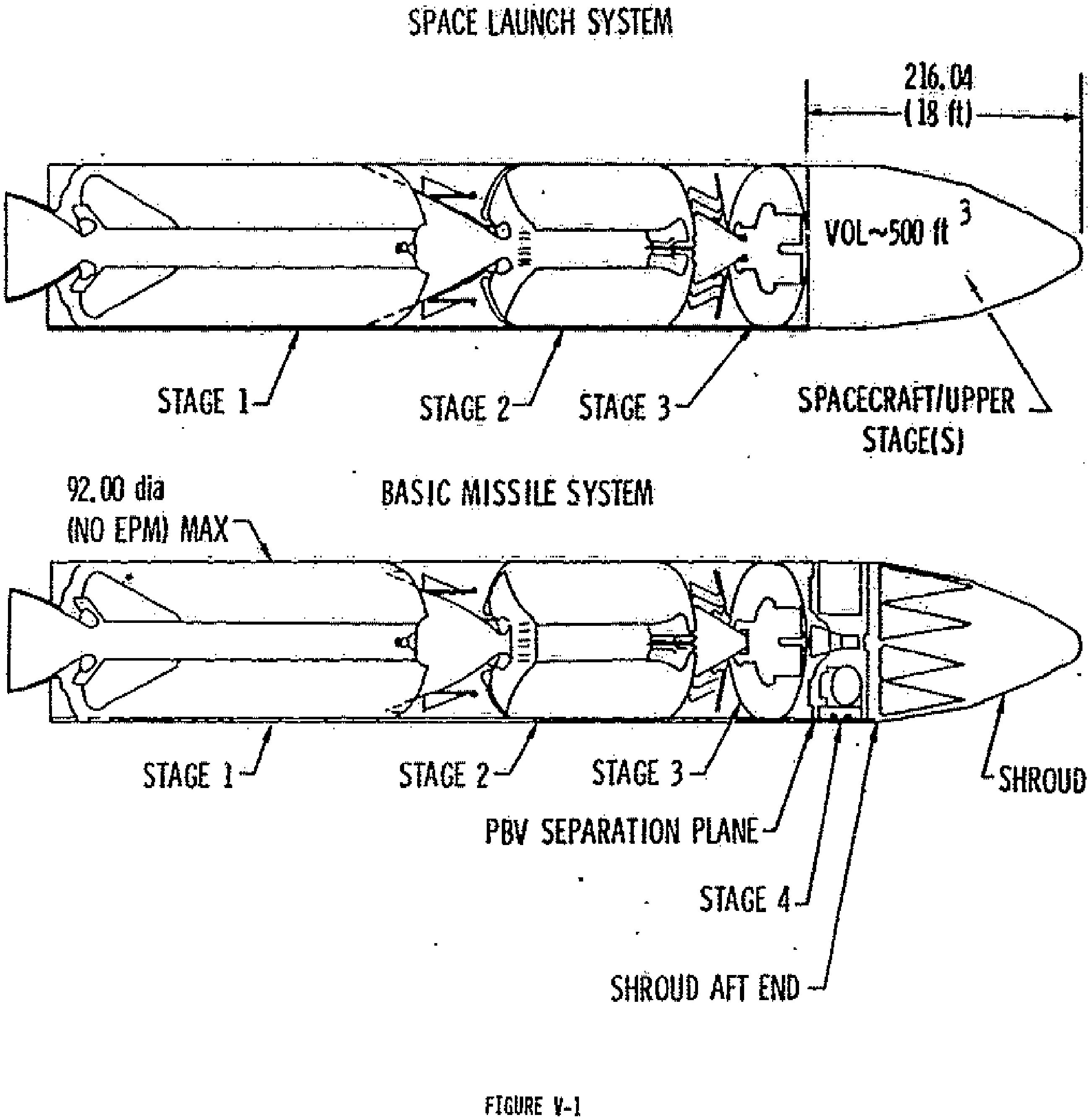


FIGURE V-1

VI ATLAS, DELTA, MX TECHNICAL RISK

The technical risk for other ELV candidates is minimal for those vehicles currently in production; i.e., the Atlas H and Delta 3310. The risks associated with the Atlas K and Delta 4920A/PAM are moderate-to-low since these vehicles are not presently in development. Available information on MX as a space launch vehicle is not sufficient to make a confident technical risk assessment.

VII ELV COST COMPARISON

A cost comparison of the Titan II, the Atlas, and the Delta vehicles is shown in Figures VII-1 and VII-2 for the DMSP and GPS missions, respectively. The cost data indicates that the modified Titan II is the most economically attractive ELV for the total payload class requirements.

Titan II Space Launch Vehicle

COST PER FLIGHT COMPARISON
DMSP (1990 DOLLARS)

	TITAN II	ATLAS		DELTA 3310
		H	K	
HARDWARE	14.9	46.4	48.2	29.0
INTEGRATION	2.3	*	*	*
LAUNCH SERV	16.4	19.3	19.3	11.7
NONRECURRING AMORTIZED	5.9	0.0	3.3	0.8
	39.5	65.7	70.8	41.5

*Integration costs are included in the Launch Services

DOLLARS IN MILLIONS

FIGURE VII-1

Titan II Space Launch Vehicle

COST PER FLIGHT COMPARISON
GPS (1990 DOLLARS)

	TITAN II CASTOR IV	ATLAS K	DELTA 4920
HARDWARE	32.3	48.2	60.0
INTEGRATION	2.5	*	*
LAUNCH SERV	11.5	16.2	11.7
NONRECURRING AMORTIZED	7.7	3.3	2.5
	54.0	67.7	74.2

*Integration costs are included in the Launch Services

DOLLARS IN MILLIONS

FIGURE VII-2

VIII CONCLUSIONS

Several Expendable Launch Vehicle configurations (Titan II, Atlas, Delta) exist or have been proposed which could meet the performance requirements of the DMSP and GPS class payloads. The technical and cost analyses performed indicate that the Titan II space launch vehicle is the preferred alternative for these missions for the following reasons:

- While modifications to the Titan II are needed to support GPS, use of Atlas or Delta for GPS requires design and build of new vehicle configurations.

- On a total program unit cost basis, the Titan II is cheaper for DMSP and GPS class missions than either Atlas or Delta. The situation is further improved if NOAA elects to convert to the Titan II launch vehicle, because non-recurring costs could be shared with them, thus, reducing the overall DOD costs.

- Use of Titan II can be justified as a cost-effective use of existing Government assets in which there are considerable sunk costs and relatively low cost per flight.

The technical review of the Titan II space launch program indicates that it is low risk with little development schedule concurrency. A program go-ahead on 1 Oct 85 will support a first launch in FY89 as required.

Evaluation of the cost impacts of implementing a Titan II program on the DOD, on all U.S. Government agencies (including DOD) and on all Shuttle users indicates that for a relatively small near term investment, substantial long term savings may be realized by the DOD and by the total of all U.S. Government agencies. Some impact could be felt by the commercial/foreign Shuttle users if some of the Shuttle launch opportunities available as a result of use of Titan II are not resold by NASA.

Additional studies are required on MX as a space launch vehicle to define the technical requirements on both the launch vehicle and the payloads.

Efforts should continue, as currently directed in the PMD, to store deactivated Titan II vehicles and equipment to protect the option to use these vehicles as space launch vehicles. Favorable competition of the Titan II space launch vehicle alternative in the FY86-90 POM process will allow development and implementation of a versatile expendable launch capability with the potential for large cost savings.

10 February 1984

APPENDIX

I TITAN II

A. Introduction

With the phaseout of Titan II as a weapon system, consideration has been given to utilization of this vehicle as an expendable space launch vehicle for small payloads.

Studies indicate that use of Titan II as a space launch vehicle is technically feasible and cost effective.

The first operational flight of Titan II was in March 1962. The last 28 out of 29 Titan II operational test flights have been successful. The deactivation program, which started in July of 1982, is currently scheduled for completion in 1987. At that time, a fleet of 56 Titan IIs will be available for the space launch vehicle program.

B. Reliability

A concern about use of the operational Titan II was the possible degradation of the system due to aging. To obtain information on the integrity of the Titan II system on a "real-time" basis, the following programs were developed by SAC/AFLC and are currently in use:

1) Reliability, Aging, and Surveillance Program (RASP) - "Detection of time-related or other non-random aging modes to predict problems prior to occurrence and initiate corrective action."

2) Service Life Analysis Program (SLAP) - "Evaluate the capability of the engines to fulfill mission requirements after an extended shelf life."

Because of the SLAP/RASP testing program, increased confidence has been obtained in the Titan II flight hardware. Further confidence has been gained by assembling complete build/repair/modification data packages on each Titan II. While in storage, the vehicles will continue to undergo periodic maintenance checks.

The evolution of the Titan from the early 1960s encompasses numerous design changes, performance improvements, and changes in program scope. Technical information has been exchanged between the Titan II and Titan III programs as problems and/or design changes occured. The net result is that the application of the Titan II as a space launch vehicle will represent a combination of both Titan II and Titan III technology.

APPENDIX

It is proposed that the reliability of each Titan II be maintained or improved by the items listed by major component below:

1) Engines - Refurbish and hot fire

2) Guidance - Modification and full acceptance test

3) Airframe - Complete inspection and leak test

4) Electrical - Install Titan III wiring

5) Instrumentation - Install Titan III telemetry system

C. Booster Description

Two modified Titan II configurations were considered for use as space launch vehicles.

1. Configuration One

This configuration is planned for the lighter, low altitude portion of the small payload spectrum (DMSP, NOAA and STP). It utilizes an 8 foot x 26 foot payload fairing.

a. Modification of the forward skirt is required to take increased airloads due to the longer payload fairing. Some stiffener brackets would be added to the skirt. A preliminary conceptual design for the adaptation of the fairing and payload to the booster is shown in Figure AI-1. This design is derived through the use of an 8 foot payload fairing and attachment requirements.

b. Incorporation of digital flight controls is required because the Titan II structural strength was defined for a very short nose cone configuration which imposed minor aerodynamic loading. In order to achieve a reasonable launch availability with the 26 foot long payload fairing, a load relief autopilot is required. The existing Titan II autopilot has limited capability and would require extensive modification. In addition a sensor would be required to measure body accelerations in order to provide load relief.

c. The decision to remove the vernier system is based upon the cost to replace or refurbish this system and because it is not necessary based upon DMSP requirements.

d. A new light weight guidance truss will be used to eliminate a 150 pound ballast. The new harness and battery requirement necessitates revised brackets.

Titan II - Structural Modifcations

8 FT PAYLOAD FAIRING

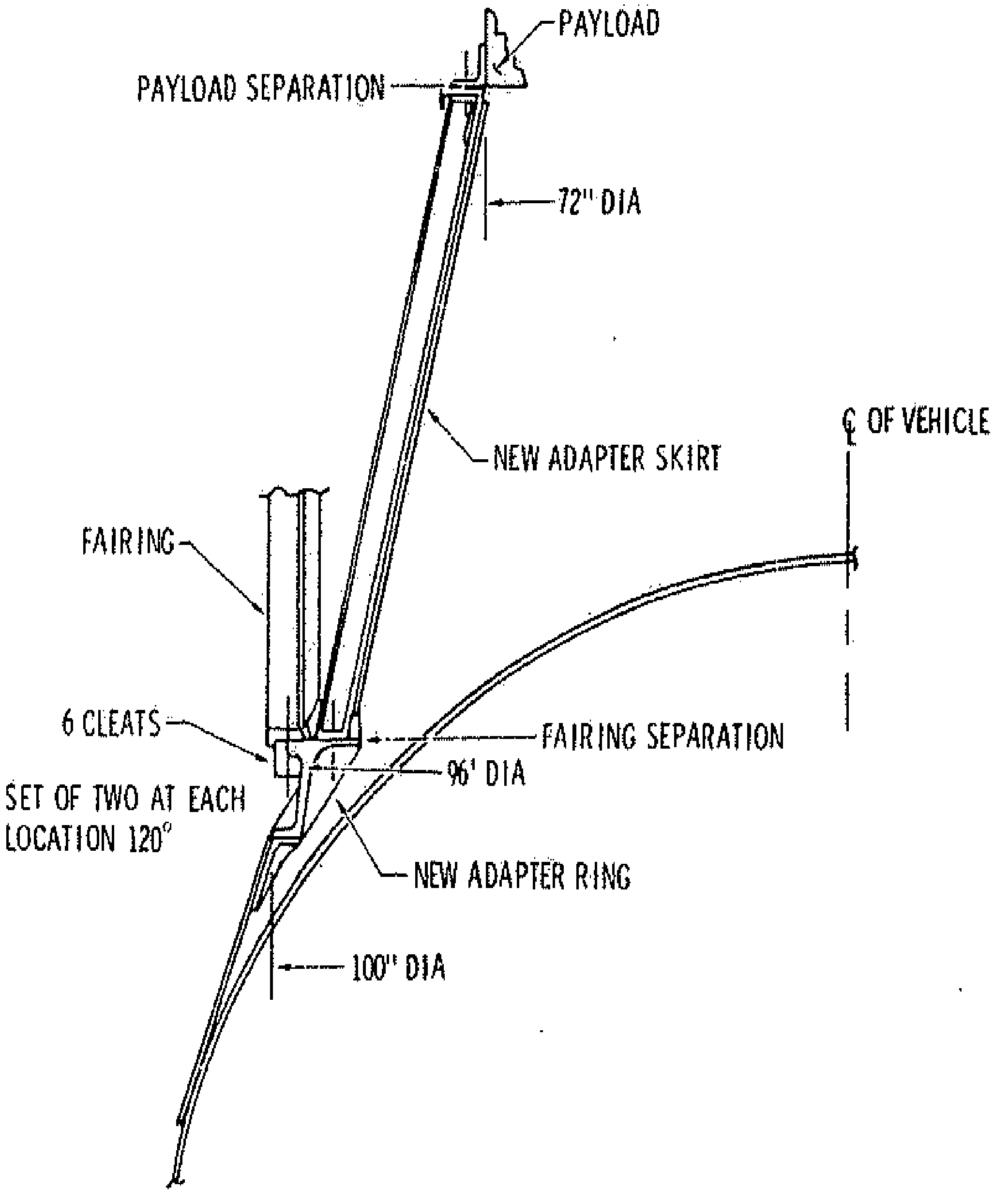


FIGURE AI-1

APPENDIX

e. The Titan II liquid rocket engines will be overhauled/retested in a program similar to the Atlas E engine overhaul program that dramatically increased the reliability of those liquid rocket engines by bringing them to a virtual "as new" condition. The engine system preparation will begin with a complete, detailed review of the engine records, including all service records, to provide a baseline of the engine condition before refurbishment.

The engines will be returned to the contractor for disassembly and inspection. The turbo-pump assembly will be hot fired (full duration). All soft goods will be replaced. New electrical wiring harnesses will be installed and the engine will be test fired (hot fired) for a 20-second truncated duration the same as has been proven on the Titan III program to be the test duration needed to uncover problems. After this, the engine will be subjected to the usual post fire disassembly, cleaning and reassembly. Engine functions and leak check procedures will be performed and the engines will then be delivered to the Air Force.

2. Configuration Two

This configuration is planned for the heaviest and highest mission requirements for the Titan II ELV — the GPS mission requirements. The basic modifications for this configuration are very similar to Configuration One. In addition, Configuration Two utilizes a 10 foot x 30 foot payload fairing; and the performance is increased by the addition of four CASTOR IV strap-on solid rocket motors.

a. To incorporate the 10 foot diameter skirt to support the payload fairing, it is necessary to remove and replace the forward dome of the Stage II tank and replace it with a new K frame and a new dome. This will require a hydrostatic test of the rebuilt tank. The configuration change to the forward dome is needed to provide the structure for payload and fairing attachment; the dome and skirt structure will give load carrying capability for the payload and provide for attachment of the larger diameter payload fairing.

Removing the previous forward dome and rewelding a new skirt and dome is a well-practiced procedure, having been completed on each Atlas launch vehicle to provide for payload fairing mounting attachments and increased forward loads. On the Atlas program, this "ring" welding is done on a production basis at the contractor's facility.

b. Unlike Configuration One, the vernier system will be retained. The vernier solid rocket motors will, however, be replaced because of age. The vernier hydraulic system will be refurbished. The requirement for the vernier system in this case is driven by the GPS mission which requires post-SECO maneuvers.

Titan II/GPS Configuration

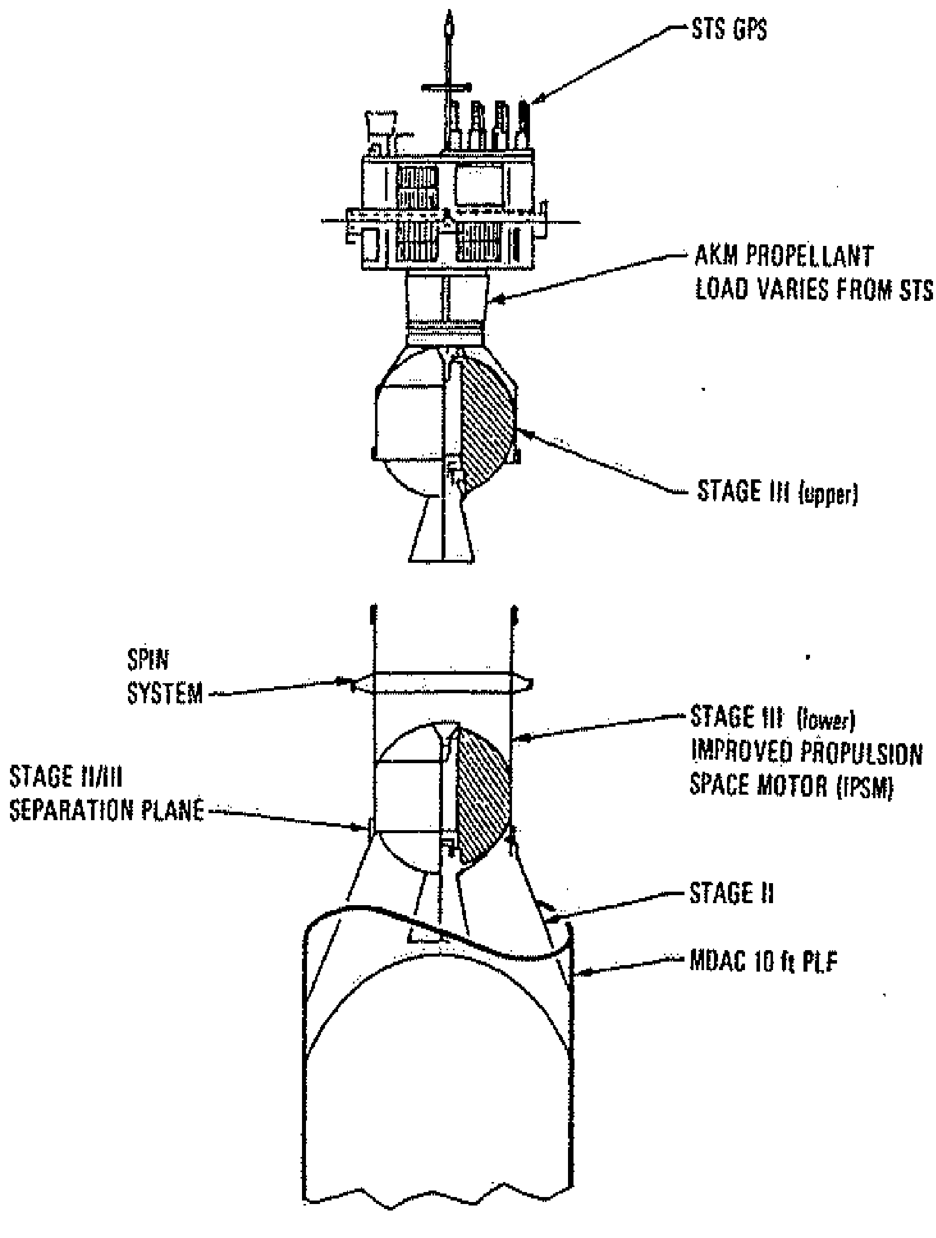


FIGURE AI-2

Titan II Space Launch Vehicle

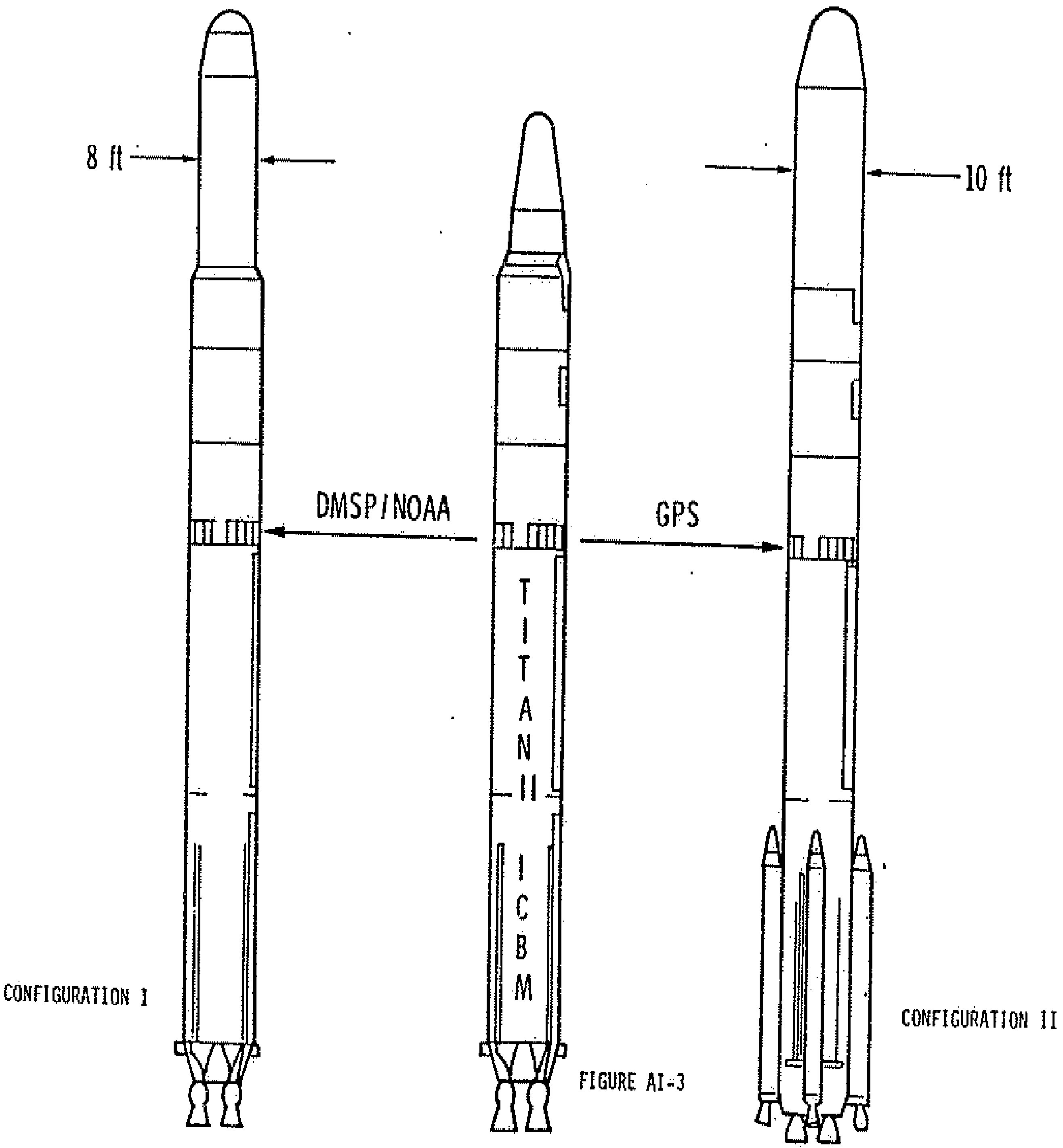


FIGURE AI-3

c. Configuration Two will be provided with a third stage (Figure AI-2). This upper stage will be similar to the stage flown on the Atlas E for GPS. The STAR 48 solid motors will be replaced by Improved Propulsion Space Motors (IPSMs).

d. The primary configuration difference between Configurations One and Two is the addition of four CASTOR IV strap-on solid rocket motors. These motors are burned two at a time--the first set, from booster liftoff until approximately 60 seconds after liftoff; the second pair ignites at 60 seconds and are jettisoned at 120 seconds. This addition will require modification to Stage I of the Titan II to strengthen and provide structure for the CASTOR attachments and separation mechanism. Figure AI-3 provides a comparison of Configurations One and Two.

D. Modification Plan

1. The method of modifying the Titan IIs into ELVs differs with configuration. For Configuration One, the entire modification will be performed at Vandenberg AFB (VAFB) by the launch crew. Kits will be provided by the contractor which will include structural details, adapters, modified and new boxes, and all refurbished hardware. The engines and guidance system will be delivered to VAFB from their respective contractors for installation by the launch crew. Vehicles will be stored at Norton AFB prior to shipment to VAFB. The engines and guidance system will be removed at Norton AFB and shipped to the appropriate facility for modification, retest and refurbishment.

2. For Configuration Two, the modification plan will differ. The vehicle (without engines and guidance system) will be shipped to the contractor's facilities and the heavy structural modification (such as the Stage II forward skirt on Configuration Two and the CASTOR IV-required Stage I modification) will be accomplished in the factory. The vehicle will then be shipped to VAFB and the launch crew will complete all other modifications as done for Configuration One. This approach maximizes the utilization of the fixed level of personnel required to provide a launch team. The existing launch teams have demonstrated the capability to change out virtually all of the hardware on a vehicle and to make field modifications.

E. Payloads

In the study of Titan II as a space launch vehicle, four payload candidates were considered: DMSP, NOAA, STP and GPS. See Figure AI-4, "Titan II Space Launch Candidates", for the requirements of each of these four candidates and the capability of the Titan II for each mission. Assuming all launches from VAFB, Titan II Configuration One has adequate capability with minimal modifications for both DMSP, NOAA and STP. This configuation is inadequate for the requirements of GPS. To obtain sufficient performance to boost GPS to its 10,898 nautical mile circular orbit, Titan II requires the addition of four CASTOR IV motors and a third stage. GPS and DMSP are

Titan II Space Launch Candidates
VAFB LAUNCH

PROGRAM	ORBIT (NM)/INCL	REQUIREMENT (LBS)	CAPABILITY (LBS)
TITAN II			
DMSP	450 CIRC/i = 98.7°	2284	2669
NOAA	SIMILAR TO DMSP		
STP	250 CIRC/i = 90°	<4300	4300
GPS	10,898 CIRC/i = 55°	2285	1952
TITAN II/ CASTOR IV			
GPS	10,898 CIRC/i = 55°	2285	2497

FIGURE AI-4

currently launched on Atlas E from Vandenberg, although GPS is scheduled for Shuttle launches from Kennedy Space Center in 1986. The impact on both the DOD and all users of deleting these flights from the Shuttle traffic model will be discussed in the Cost Section.

1. Configuration One was structured around the DMSP/NOAA series and flown in the same manner as these payloads fly on ELVs today. The payload weight to orbit compares to the current known requirement of 2284 pounds.

2. Configuration Two was structured around the GPS/Block III payload which is intended to fly on STS. This program has a weight requirement on final orbit of 2285 pounds. This analysis established a capability of 2497, which provides 212 pounds of margin. This number is very conservative since class margins, no Stage I thrust uprate, and standard IPSM configuration were used.

F. <u>Launch Base</u>

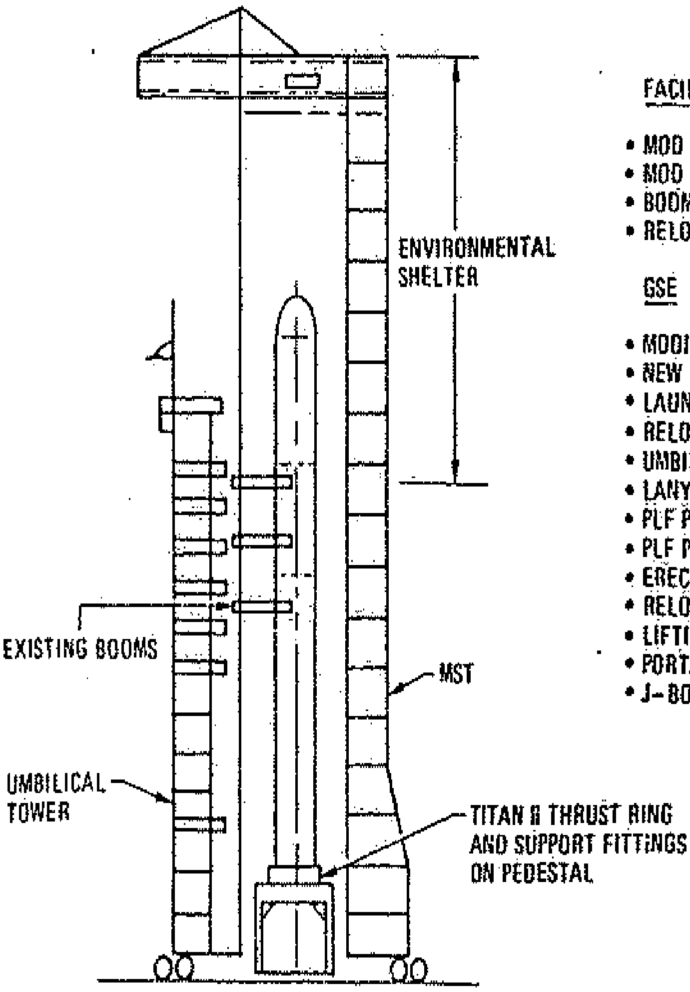
All costs, crew sizings, schedules and analyses performed were based upon utilizing the same procedural documentation, quality assurance and receipt-to-launch testing as is currently employed for the Titan III. A contractor launch crew is assumed to support a launch rate of six per year.

1. <u>Launch Site Impact</u>

The launch site selected for the Titan II ELV is the VAFB facility, Space Launch Complex-4 West (SLC-4W). This was selected because of the similarity between the Titan IIIB family of vehicles currently launched there and the Titan II ELV. The facility modification for Configurations One and Two are, in essence, the same, each being driven by the addition of a pedestal to raise the shorter Titan II so that the payload fairing and payload will be enclosed by the environmental shelter (Figure AI-5).

The vehicle checkout and launch control AGE requirements of Titan II involve very minor modifications to existing consoles and racks. The Titan III Programmable Aerospace Checkout Equipment (PACE) will continue to be the checkout system for the Titan II ELV. New PACE application sequences will be required. The most significant addition will be the installation of the guidance system checkout set (MGAC). This unit will be furnished from government surplus available from the deactivation of Titan II silos. Minimal modifications to the umbilical booms and vehicle-mounted umbilicals will be accomplished by a rotation of the vehicle by 45 degrees on the pad for Configuration One. This rotation is undesirable for Configuration Two due to the CASTOR IV's exhaust plumes. Hence, in this configuration relocation of the umbilicals will be required. The incorporation of the CASTOR IVs will also require the addition of supplementary plume exhaust ducts to ensure that their flow is injected into the main exhaust duct. The main exhaust duct is adequate. In addition to the Mobile Service Tower (MST) modification defined for Configuration One, several more platforms will require modification to accommodate the CASTOR IV motors of Configuration Two.

Facility Modifications - SLC - 4W



FACILITY MODIFICATIONS

- MOD 3 ES PLATFORMS
- MOD 6 MST PLATFORMS
- BOOM PENETRATION IN MST
- RELOCATE BOOM FACILITY MOUNTING PLATES

GSE

- MODIFY ATTACH POINTS ON EXISTING HEAD ASSEMBLY
- NEW LAUNCH MOUNT RING
- LAUNCH MOUNT ACCESS PLATFORM
- RELOCATE WATER DELUGE SPRAY
- UMBILICAL MODS (boom relocation and mods)
- LANYARD RIGGING
- PLF POSITIONING & ALIGNMENT EQUIPMENT
- PLF PROCESSING FACILITY
- ERECTION FIXTURE
- RELOCATE GOAL POST
- LIFTING ADAPTERS
- PORTABLE FLOOR CRANE
- J-BOX RELOCATION

FIGURE AI-5

APPENDIX

G. Schedules

The schedule for the two configurations is provided in Figure AI-6. The schedule was developed on the basis of the selected user need dates. In the event that both configurations were authorized, an integrated schedule would be developed.

The schedule associated with Configuration One and DMSP/NOAA usage, was developed considering that the current block of payloads end in the 1988-89 timeframe with depletion of the existing fleet of Atlas E vehicles; and the new block will commence launching in 1989. This, coupled with the desire to preserve continuity of the existing launch crew at VAFB, dictated a go-ahead in late CY 1985 so that work could commence on the facilities modification program and launch procedures in a smooth transition with the phasedown of current Titan III ELV activity.

H. Technical Risk Assessment

Technically, the fact that all of the modifications, replacements and additions are using existing Titan III technology and hardware makes this program extremely low risk. Also, both SLAP and RASP test results imply that a very low fallout of Titan II hardware will occur in the refurbishment and re-acceptance program.

In view of the fact that for Configuration Two a new upper stage and incorporation of the CASTOR IV strap-ons are to be developed, a 30-month schedule would seem to present some risk. This concern can be minimized by recognizing that the new stage incorporates a totally developed and tested motor, and that the CASTOR IV motor is also off-the-shelf, requiring no modification. Previous experience incorporating strap-on solids on the Titan III also contributes to minimizing the concern. Further, recognizing that the upper stage consists basically of a solid rocket motor and a propulsive spin system adapted from an existing stage, also alleviates these concerns.

The higher thrust and heavier payload for Configuration Two will require analyses and testing. The structural design will need to be stiffened and/or strengthened in the areas of the tank bottom and CASTOR IV attachments. Formal overall structural testing will be required to ensure flight reliability of the modified structure.

Based on the reasons presented above, the technical risk is assessed as low.

Titan II Conversion to Space Launch Vehicle

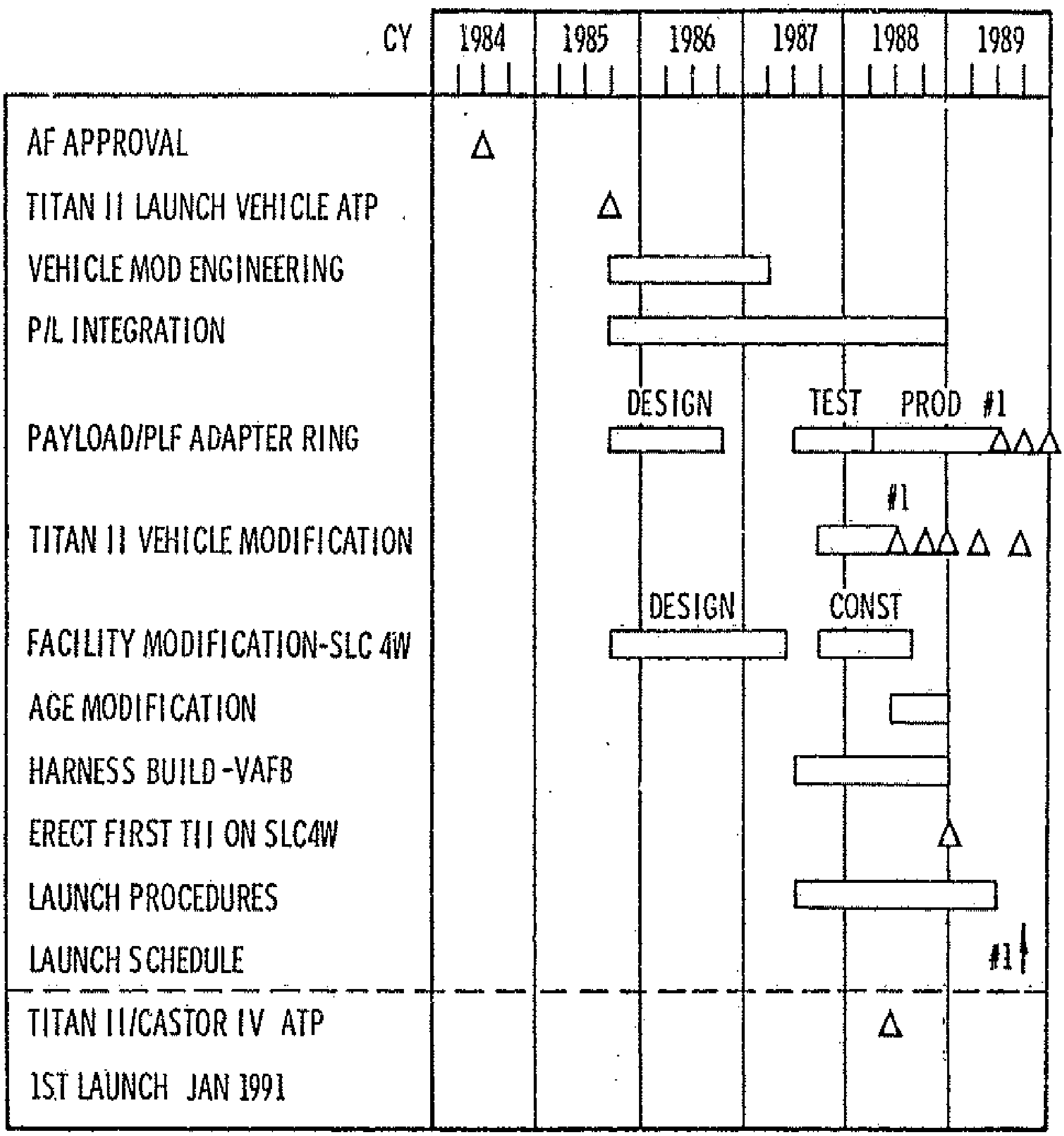


FIGURE AI-6

APPENDIX

I Cost Estimate

1. Titan II Cost Estimate

The non-recurring development and the recurring modifications and operation costs for the two configurations of Titan II reflect contractor cost estimates adjusted to account for program costs not included by contractors and for future unknowns. These cost estimates are based upon a first quarter FY86 go-ahead supporting a late-FY89 Initial Launch Capability (ILC) for Configuration One and a mid-FY88 go-ahead supporting an early FY91 ILC for Configuration Two.

APPENDIX

To develop the cost to implement the Titan II program, th following assumptions were made:

- Configuration One - DMSP/NOAA/STP Launch Model

  15 vehicle Titan II program

89	90	91	92	93	94
1	4	3	3	2	2

- Configuration Two - GPS Launch Model

  16 vehicle Titan II program

91	92	93	94
4	4	4	4

- All launches from VAFB

- Cost of propellant assumed to be zero

- Non-recurring cost includes:
  - Design
  - Manufacturing
  - Launch site modifications and upgrade
  - Skill retention (gap costs)
  - Integration

- Recurring costs include:
  - Booster build
    - Airframe kit
    - VAFB assembly
    - Technical support
  - Guidance
  - Engine refurbishment
  - Payload fairing
  - Launch costs
  - Range support
  - Recurring integration

2. <u>Cost Impacts</u>

To determine the cost impact of launching Titan II space vehicles, as shown in Figures AI-7, AI-8 and AI-9, the following analysis was made assuming as a baseline case that NASA can resell the deleted GPS missions at KSC (no deleted VAFB flights resold). In addition, Figures AI-10, AI-11 and AI-12 show the cost effects if NASA is unable to resell any flights.

IMPACT TO DOD

GPS RESOLD

THEN YEAR M $

FY	86	87	88	89	90	91	92	93	94	TOTAL
TITAN II COSTS	50.9	77.5	116.7	150.5	166.1	242.3	276.4	131.6	129.8	1341.8
SHUTTLE FLT CHG SAVINGS*				-277.2	-419.3	-449.2	-481.0	-515.2		-2141.9
PAYLOAD DESIGN SAVINGS (DMSP)	-4.5	-40.4	-23.8	-11.3						-80.0
STS IMPACT COST (DOD) *			19.2	70.2	30.2	46.6	49.9	53.4		269.5
DOD TOTAL IMPACT	46.4	37.1	112.1	-67.8	-223.0	-160.3	-154.7	-330.2	129.8	-610.6

NOTE: (-) INDICATES SAVINGS

*ASSUMES FULL COST RECOVERY FOR SHUTTLE IN THE RATIO OF SHUTTLE FLT CHARGES PER PAYLOAD SHOWN BELOW

DMSP=1
GPS=.33
STP=.5
NOAA=.5

FIGURE AI-7

IMPACT TO U.S. GOVERNMENT
GPS RESOLD
THEN YR M $

FY	86	87	88	89	90	91	92	93	94	TOTAL
STS IMPACT COST (NASA)			8.8	74.7	63.3	55.6	59.7	63.8		325.9
NOAA SHUTTLE FLT CHG SAVINGS			-64.7	-69.3	-74.3	-79.5	-85.2	-91.2		-464.2
PAYLOAD DESIGN SAVINGS (NOAA)	-2.8	-25.3	-14.9	-7.0						-50.0
DOD TOTAL IMPACT*	46.4	37.1	112.1	-67.8	-223.0	-160.3	-154.7	-330.2	129.8	-610.6
GOVT TOTAL IMPACT	43.6	11.8	41.3	-69.4	-234.0	-184.2	-180.2	-357.6	129.8	-798.9

NOTE: (-) INDICATES SAVINGS
*ASSUMES FULL COST RECOVERY FOR SHUTTLE IN THE RATIO OF SHUTTLE CHARGES PER PAYLOAD SHOWN BELOW

DMSP=1
GPS=.33
STP=.5
NOAA=.5

FIGURE AI-8

IMPACT TO ALL USERS
GPS RESOLD
THEN YEAR M $

FY	86	87	88	89	90	91	92	93	94	TOTAL
GOVT TOTAL IMPACT	43.6	11.8	41.3	-69.4	-234.0	-184.2	-180.2	-357.6	129.8	-798.9
STS IMPACT (COMM & FOREIGN)			9.6	54.9	34.0	36.4	39.0	41.7		215.6

NOTE: (-) INDICATES SAVINGS

*ASSUMES FULL COST RECOVERY FOR SHUTTLE IN THE RATIO OF SHUTTLE FLT CHARGES PER PAYLOAD SHOWN BELOW

DMSP=1
GPS=.33
STP=.5
NOAA=.5

FIGURE AI-9

IMPACT TO DOD

THEN YEAR M $

FY	86	87	88	89	90	91	92	93	94	TOTAL
TITAN II COSTS	50.9	77.5	116.7	150.5	166.1	242.3	276.4	131.6	129.8	1341.8
SHUTTLE FLT CHG SAVINGS*				-277.2	-419.3	-449.2	-481.0	-515.2		-2141.9
PAYLOAD DESIGN SAVINGS (DMSP)	-4.5	-40.4	-23.8	-11.3						-80.0
STS IMPACT COST (DOD)			19.2	70.2	59.4	92.8	99.4	106.5		447.5
DOD TOTAL IMPACT	46.4	37.1	112.1	-67.8	-193.8	-114.1	-105.2	-277.1	129.8	-432.6

NOTE: (-) INDICATES SAVINGS

*ASSUMES FULL COST RECOVERY FOR SHUTTLE IN THE RATIO OF SHUTTLE FLT CHARGES PER PAYLOAD SHOWN BELOW

DMSP=1
GPS=.33
STP=.5
NOAA=.5

FIGURE AI-10

IMPACT TO U.S. GOVERNMENT

THEN YR M $

FY	86	87	88	89	90	91	92	93	94	TOTAL
STS IMPACT COST (NASA)			8.8	71.6	164.0	138.6	148.4	158.9		690.3
NOAA SHUTTLE FLT CHG SAVINGS			-64.7	-69.3	-74.3	-79.5	-85.2	-91.2		-464.2
PAYLOAD DESIGN SAVINGS (NOAA)	-2.8	-25.3	-14.9	-7.0						-50.0
DOD TOTAL IMPACT*	46.4	37.1	112.1	-67.8	-193.8	-114.1	-105.2	-277.1	129.8	-432.6
GOVT TOTAL IMPACT	43.6	11.8	41.3	-72.5	-104.1	-55.0	-42.0	-209.4	129.8	-256.5

NOTE: (-) INDICATES SAVINGS
*ASSUMES FULL COST RECOVERY FOR SHUTTLE IN THE RATIO OF SHUTTLE CHARGES PER PAYLOAD SHOWN BELOW

DMSP=1
GPS=.33
STP=.5
NOAA=.5

FIGURE AI-11

IMPACT TO ALL USERS

THEN YEAR M $

FY	86	87	88	89	90	91	92	93	94	TOTAL
GOVT TOTAL IMPACT	43.6	11.8	41.3	-72.5	-104.1	-55.0	-42.0	-209.4	129.8	-256.5
STS IMPACT (COMM & FOREIGN)			9.6	54.9	89.2	95.4	102.2	109.5		460.8

NOTE: (-) INDICATES SAVINGS

*ASSUMES FULL COST RECOVERY FOR SHUTTLE IN THE RATIO OF SHUTTLE FLT CHARGES PER PAYLOAD SHOWN BELOW

DMSP=1
GPS=.33
STP=.5
NOAA=.5

FIGURE AI-12

APPENDIX

a. Titan II Costs

The Titan II implementation costs (Figure AI-13) reflect a 31 vehicle program with the first launch in 1989 and the last launch in 1994. The launch program can, however, be extended beyond 1994. Although Figure AI-13 reflects NOAA sharing the non-recurring development costs, in our DOD impact analysis no NOAA sharing was assumed.

b. Shuttle Flight Charge

The Shuttle-equivalent flights saved by the Titan II flights flown are:

			89	90	91	92	93	94
DMSP	=	1		1	1	1	1	1
STP	=	1/2		1	0	0	0	0
GPS	=	1/3		0	1-1/3	1-1/3	1-1/3	1-1/3
NOAA	=	1/2	1/2	1/2	1/2	1/2	1/2	1/2
	VAFB		1/2	2-1/2	1-1/2	1-1/2	1-1/2	1-1/2
	KSC		0	0	1-1/3	1-1/3	1-1/3	1-1/3

The impact to the DOD and all other users are calculated using a flight charge of $133 million FY83 dollars for KSC flights and $97 million FY83 dollars for VAFB flights.

The savings from these launches are realized in the year prior to launch consistent with Shuttle flight charge payment. The Shuttle cost estimate was derived from the latest NASA-available data, POP 83-2. Shuttle cost per flight history, as shown in the NASA 12 year average predictions below, reflects a steady growth.

Data Source & Date	Total Flights	Costs FY83 Dollars ($ millions)
Data Base, Jun 76	572	35.0
OMB Study, Sep 80	487	50.8
POP 81-2, Feb 82	362	74.0
NASA Computer Assessed Data Base, Feb 82	234	111.5
POP 83-2, Aug 83	232	132.7

TITAN II SPACE LAUNCH VEHICLE
TOTAL IMPLEMENTATION COSTS

(THEN YEAR $)

FY	86	87	88	89	90	POM TOTAL	91	92
DOD								
N/R								
3600	31.7	24.4	25.9	40.5	20.0	142.5		
3300	1.6	1.3	1.0	1.1	2.0	7.0		
SUB-TOTAL	33.3	25.7	26.9	41.6	22.0	149.5		
REC								
3020		19.3	24.7	26.6	68.3	138.9	142.2	149.0
3400				20.5	29.9	50.4	78.0	106.4
3600		2.0	18.2	20.7	11.6	52.5	3.2	
SUB-TOTAL		21.3	42.9	67.8	109.8	241.8	223.4	255.4
TOTAL	33.3	47.0	69.8	109.4	131.8	391.3	223.4	255.4
NOAA								
N/R	15.4	15.9	15.2	3.1		49.6		
REC	2.2	14.6	31.7	38.0	34.3	120.8	18.9	21.0
SUB-TOTAL	17.6	30.5	46.9	41.1	34.3	170.4	18.9	21.0
TOTAL	50.9	77.5	116.7	150.5	166.1	561.7	242.3	276.4

FIGURE AI-13

APPENDIX

NASA currently forecasts $112 million as the average cost per flight for the FY89-93 time period. However, based upon the roughly 20% growth in their 12 year average flight charges from the Feb 82 to Aug 83 forecast, we have placed a 20% factor on the $112 million charge yielding a flight charge of $133 million in FY83 dollars.

c. Payload Design Savings

These savings result from deleting the need to design dual ELV/Shuttle compatible spacecraft as presently planned. DMSP and NOAA could continue to procure the same basic spacecraft as now flies on Atlas-E. Savings reflect amounts in currently approved budgets.

d. STS Impact Cost

The STS operations costs are composed of both fixed and variable costs. When the STS flight model is reduced, the cost per flight of the remaining model must increase to offset the pro rata portion of the fixed costs apportioned to the deleted flights. In order to properly assess the impact of Shuttle flight rates, Shuttle flight rate dependent algorithms were derived. The algorithms were divided into three separate elements:

1) Reimbursibles (primarily consumables)

2) Flight Operations (primarily JSC operations)

3) Launch Operations (primarily KSC operations)

The cost impact on remaining Shuttle flights, due to flight deletions, was then compiled for different numbers of deleted flights as follows:

	Costs in Millions of FY83 Dollars			
Deleted Flights	1	2	3	4
Reimbursible Costs	1.33	2.78	4.36	6.11
Flight Operations (JSC)	1.05	2.19	3.44	4.81
Launch Operations (KSC)	1.71	3.61	5.74	8.13

The cost impact for the remaining KSC flights is then the summation of Reimbursible and Flight Operations cost impacts (based on total Shuttle flight deletions), plus the KSC launch operations impact based on KSC flight deletions, if any. The cost impact for the remaining VAFB flights is only the summation of Reimbursible and Flight Operations impacts. The VAFB launch costs are assumed to be held constant.

APPENDIX

On the basis of the Shuttle flight deletions, as described above in paragraph I.2.b, the following cost impacts to each remaining Shuttle flight were derived:

Deleted Flights

		Number	
VAFB	1/2	2-1/2	1-1/2
KSC	0	0	1-1/3
TOTAL	1/2	2-1/2	2-5/6

Cost Impact

		FY83 $ In Millions	
VAFB Impact	1.2	6.4	7.3
KSC Impact	1.2	6.4	9.7

The Shuttle cost impact on the DOD, NASA and commercial flights is then the remaining number of Shuttle flights (see following traffic model) times the appropriate launch site cost impacts. As it is highly likely that deleted GPS Shuttle flights will be resold, since they are PAM-DII missions, the baseline case used in this study assumed GPS Shuttle flights at KSC are resold but deleted VAFB Shuttle flights (e.g. DMSP) are not.

<u>Traffic Model</u>

	89	90	91	92	93	94	TOTAL
DOD							
AF							
KSC	6	3-2/3	5-1/3	3-2/3	3-2/3	3-2/3	26
VAFB	1	1	1	1	1	1	6
Other							
KSC	4	2	0	2	2	2	12
VAFB	1	3	0	2	2	2	10
NASA							
KSC	5	7-1/3	10-2/3	8-1/3	8-1/3	8-1/3	48
VAFB*	1	1	1	1	1	1	6
Commercial							
KSC	6	6	6	6	6	6	36
VAFB	0	0	0	0	0	0	0

* Note: While the official NASA traffic model does not show NOAA Shuttle flights, transition of NOAA would be required after their last Atlas-E flight.

APPENDIX

J. Cost Risk Assessment

This assessment has examined the cost for both completeness and reasonableness and addressed both Shuttle and ELV cost considerations.

1. Titan II

The Titan II cost risk assessment addresses the risk for total program growth.

The modifications proposed for Titan II are similar to efforts completed in the past in both the Titan III program and the Atlas overhaul program. This similarity provides confidence in both the technical and cost risk assessments. The contractor's estimate for non-recurring and recurring cost was reviewed and adjusted to include elements of cost known to have been omitted and to protect against unknowns. Based upon the above, costs are believed to be complete and reasonable.

2. Shuttle Impact

The scenarios relating to the impact to DOD and the impact to the Nation are greatly affected by the Shuttle cost per flight assumed in the 1990-1994 time period. For purposes of this study, a flight charge of $133 million in FY83 dollars was used for KSC flights as discussed in paragraph I.2.b.

3. Summary

The risk in implementing the Titan II program appears low considering both technical feasibility and cost.

II ATLAS AND DELTA LAUNCH VEHICLES

A. Atlas

The candidate Atlas vehicles are the Atlas H and Atlas K.

1. For the DMSP mission, the current Atlas H, easily satisfies the performance requirement.

2. To meet GPS performance requirements, an Atlas K with some additional tank stretch is required. The Atlas K is the Atlas H with Atlas E avionics and a tank stretch of 183 inches. Figure AII-1 depicts the Atlas H and Atlas K vehicles, and Figure AII-2 presents the performance capability of each.

B. Delta

The candidate Delta launch vehicles are the Delta 3310 and the proposed higher performer, Delta 4920A/PAM (Figure AII-3).

1. The Delta 3310 is capable of directly injecting the DMSP/NOAA payload into the final mission orbit.

2. The GPS mission requires a growth Delta. The 4920A/PAM, a proposed new vehicle, has nine CASTOR IVA motors, a 12 foot tank stretch, and a large payload fairing. The performance capability for the Delta vehicles is shown in Figure AII-4.

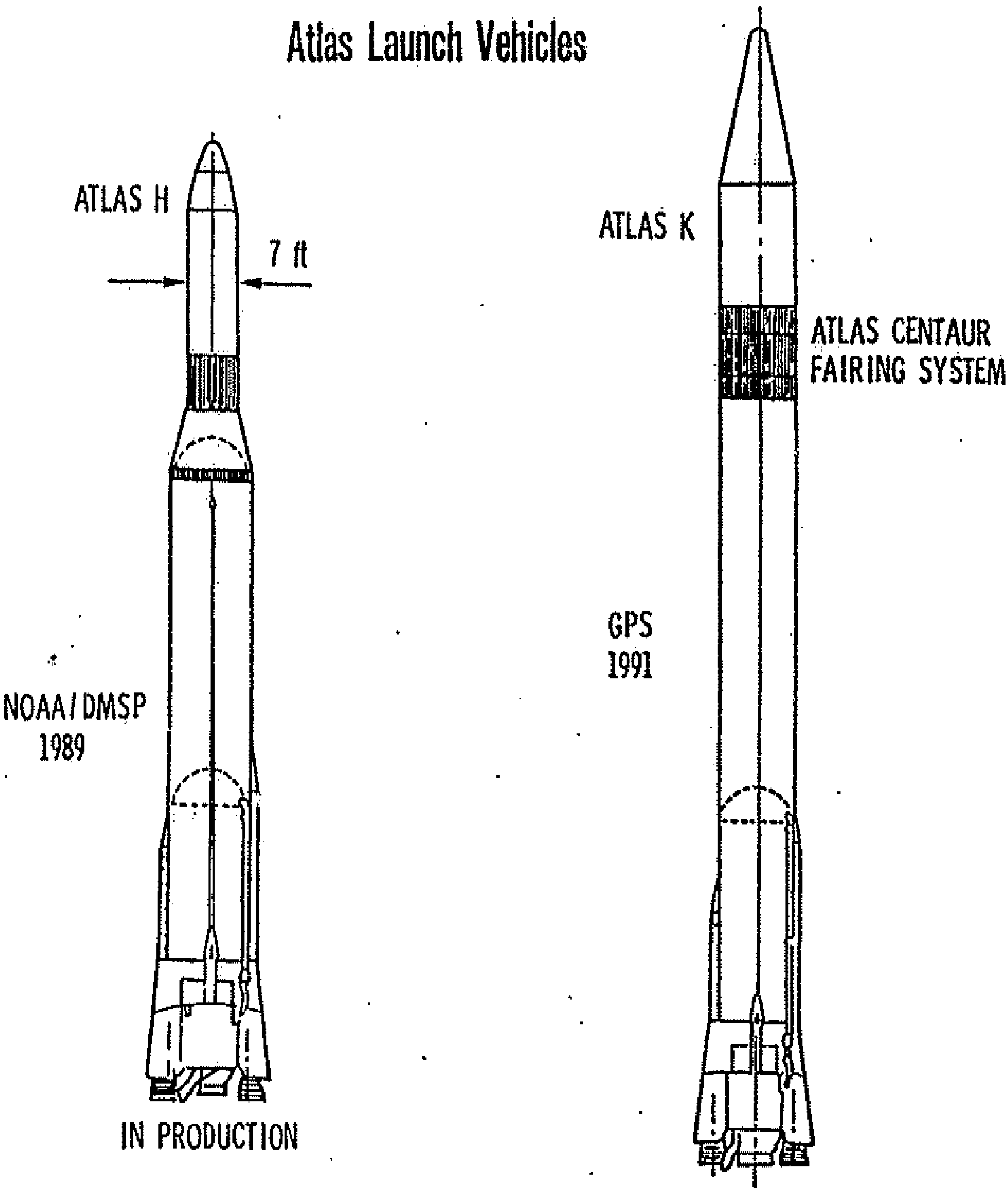
C. Technical Risk Assessment

The risk is minimal for those vehicles currently in production, the Atlas H and Delta 3310.

The risk associated with the Atlas K and Delta 4920A/PAM is moderate, since the vehicles are not presently in development.

D. Cost Comparison

A cost comparison of the Titan II, the Atlas and the Delta vehicles is shown in Figures AII-5 and AII-6 for the DMSP and GPS missions, respectively. The cost data indicates that the Titan II space launch vehicle is the most economically attractive ELV for the total payload requirements.



Atlas Launch Vehicles
ATLAS H
7 ft
NOAA/DMSP
1989
IN PRODUCTION
ATLAS K
ATLAS CENTAUR
FAIRING SYSTEM
GPS
1991

FIGURE AII-1

Atlas
PERFORMANCE CAPABILITY
VAFB LAUNCH

ORBIT (NM)	VEHICLE	REQUIREMENT (LB)	CAPABILITY (LB)
450 CIRC	ATLAS H	2284	3000
10898 CIRC	ATLAS K*	2285	2180

*ATLAS H TANK STRETCHED 183"

(FURTHER STRETCH REQUIRED TO MEET GPS PERFORMANCE REQUIREMENT)

FIGURE AII-2

Delta Launch Vehicles

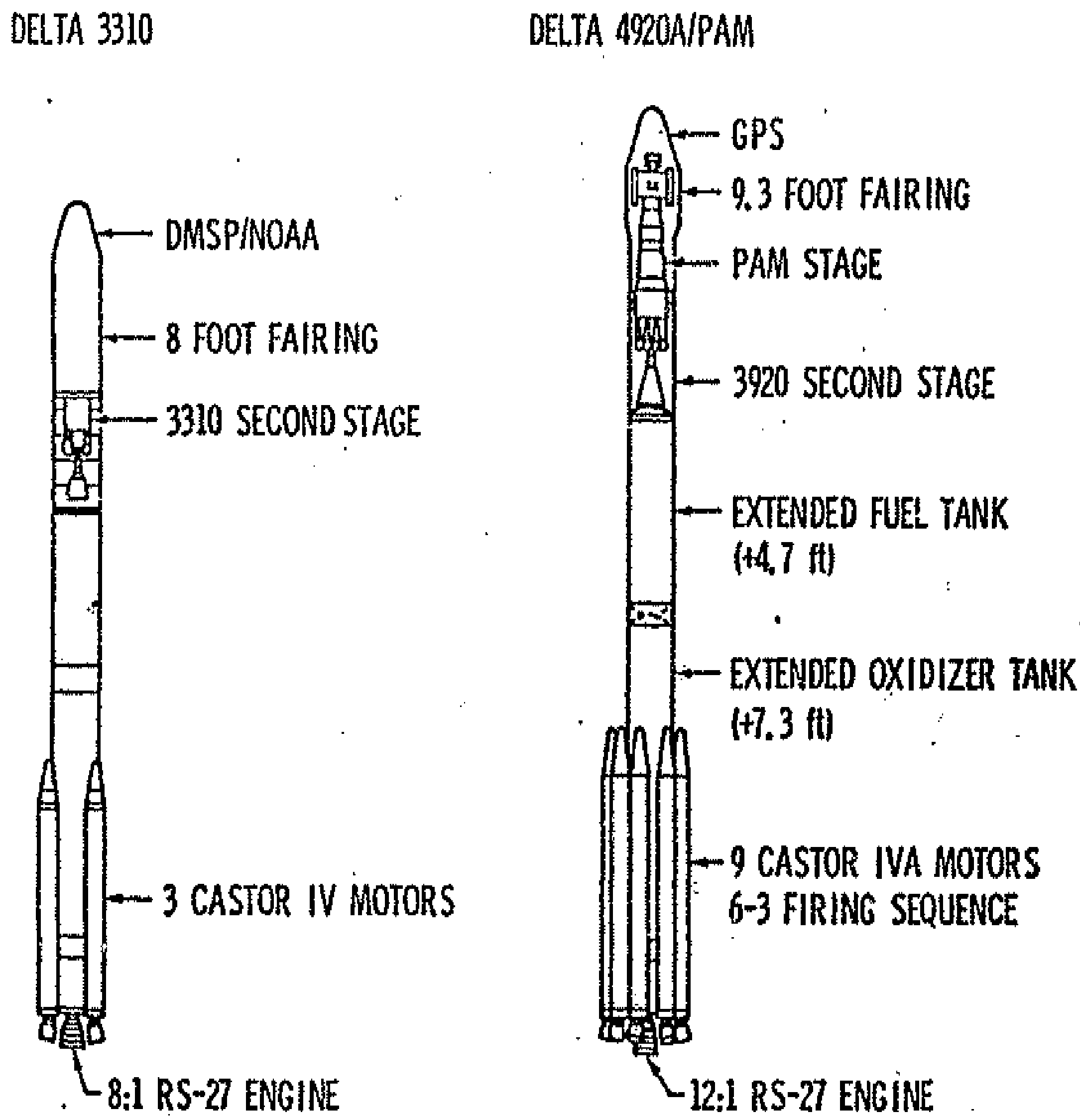


FIGURE AII-3

Delta Performance Capability

VAFB LAUNCH

ORBIT (NM)	VEHICLE	REQUIRMENT (LB)	CAPABILITY (LB)
450 CIRC	3310	2113*	2200**
10898 CIRC	4920A/PAM***	2285	2390

* S/C AKM AND N_2H_4 SYSTEM NOT REQUIRED

** WITH S/C BOOST GUIDANCE 80 LB INCREASED PERFORMANCE

*** DELTA WITH TANK STRETCHED ~12 FT

FIGURE AII-4

Titan II Space Launch Vehicle

COST PER FLIGHT COMPARISON
DMSP (1990 DOLLARS)

	TITAN II	ATLAS H	ATLAS K	DELTA 3310
HARDWARE	14.9	46.4	48.2	29.0
INTEGRATION	2.3	*	*	*
LAUNCH SERV	16.4	19.3	19.3	11.7
NONRECURRING AMORTIZED	5.9	0.0	3.3	0.8
	39.5	65.7	70.8	41.5

*Integration costs are included in the Launch Services

DOLLARS IN MILLIONS

FIGURE AII-5

Titan II Space Launch Vehicle
COST PER FLIGHT COMPARISON
GPS (1990 DOLLARS)

	TITAN II CASTOR IV	ATLAS K	DELTA 4920
HARDWARE	32.3	48.2	60.0
INTEGRATION	2.5	*	*
LAUNCH SERV	11.5	16.2	11.7
NONRECURRING AMORTIZED	7.7	3.3	2.5
	54.0	67.7	74.2

*Integration costs are included in the Launch Services

DOLLARS IN MILLIONS

FIGURE AII-6

APPENDIX

III MX

A. General Background and Previous Studies

Several studies relating to reconstitution of critical space assets have been performed since the mid-1970s. They were initiated by a continuing interest in developing alternative approaches to reconstitution of space functions.

A series of critical missions were identified, and the MX and other existing or in-development missile and space launch systems, were considered as potential booster candidates.

The results from these activities indicated a limited, but useful capability was available in the MX to support some of the identified missions. The technical feasibility of utilizing the MX as a survivable space launcher has been explored in some depth with the latest investigation reported in classified documentation released in November 1983.

COMPLEMENTARY SPACE LAUNCH STRATEGY

FOR

ASSURED ACCESS TO SPACE

FUTURE MISSIONS

10 FEBRUARY 1984

HEADQUARTERS SPACE DIVISION
AIR FORCE SYSTEMS COMMAND (AFSC)
United States Air Force
P. O. Box 92960, Worldway Postal Center
Los Angeles, California 90009

TABLE OF CONTENTS

I INTRODUCTION

DOD has become increasingly reliant upon space systems to provide for national security. Due to this fact, current Defense Space Policy states that: "while affirming its commitment to the STS, DOD will ensure the availability of an adequate launch capability to provide flexible and operationally responsive access to space, as needed for all levels of conflict, to meet the requirements of national security missions".

The potential growth of DOD payloads to weights beyond the capability of the current Shuttle, has thus generated DOD interest in Shuttle derived Unmanned Launch Vehicles (ULVs). These vehicles could achieve payload capabilities of two to three times the capability of the Shuttle. During the past ten years, heavy lift launch vehicles, including Shuttle derived versions, have been examined by NASA for a number of applications. However, it is only recently that a DOD need for such a vehicle has been envisioned and only very limited DOD resources have been expended on studying heavy lift launch systems. Although firm requirements for the ULV have not been yet established, projected DOD programs may require payload capabilities in the range of 130,000 to 200,000 pounds, with payload dimensions of approximately 25 feet diameter by 90 feet long. In order to maintain secure operations, it is also desirable to launch as many payloads as possible from Vandenberg AFB (VAFB). It is likewise desirable to minimize the costs associated with the launch of DOD payloads by adopting ground and flight operational procedures more akin to those utilized by Expendable Launch Vehicles.

The ULV is not intended to eliminate the need for the current Space Transportation System (STS). It will, however, provide a complementary vehicle to the STS. To the maximum extent practical, it will also be compatible with STS facilities and operations at both KSC and VAFB.

The ULV program will be a DOD controlled and managed development program which will support autonomous, secure DOD space operations in the mid-1990s. As appropriate and required, it is envisioned that NASA Shuttle resources and expertise will be used in areas which will benefit the effort. Depending on need, a growth version could later be developed to support more ambitious space operations early in the next century. The potential for such growth should be designed into the baseline system.

II VEHICLE DESCRIPTION

The ULV is defined as a vehicle which makes maximum cost-effective use of existing Space Shuttle technology and components and will have the capability to launch payloads which are much heavier than the current Shuttle. The major Shuttle components utilized by the ULV are: the Space Shuttle Main Engines (SSMEs), the Solid Rocket Boosters (SRBs), and the External Tank (ET). Many of the performance improvements proposed for the Shuttle (for instance, uprating the SSMEs, filament wound Solid Rocket Booster cases, or substituting Liquid Rocket Boosters for the current SRBs) can be directly applied to the ULV.

The ULV configurations have been separated into two generic concepts: In-Line versions in which the payload and the SSMEs are installed in-line with the External Tank; and the Side-Mount versions in which the payload and the SSMEs are installed in essentially the same geometric relationship to the External Tank as in the current Shuttle.

Characteristics typical of the Unmanned Launch Vehicle configurations are as follows:

A IN-LINE (Figure II-1)

Two SSMEs operating at a 100% power level.

Two standard (steel case) Solid Rocket Boosters

A shortened External Tank (ET).

A payload module mounted on top of the ET capable of carrying a 90 feet by 25 feet payload.

B SIDE-MOUNT (Figure II-2)

Three SSMEs operating at a 100% power level.

Two standard (steel case) Solid Rocket Boosters.

Reference In-Line ULV Configuration

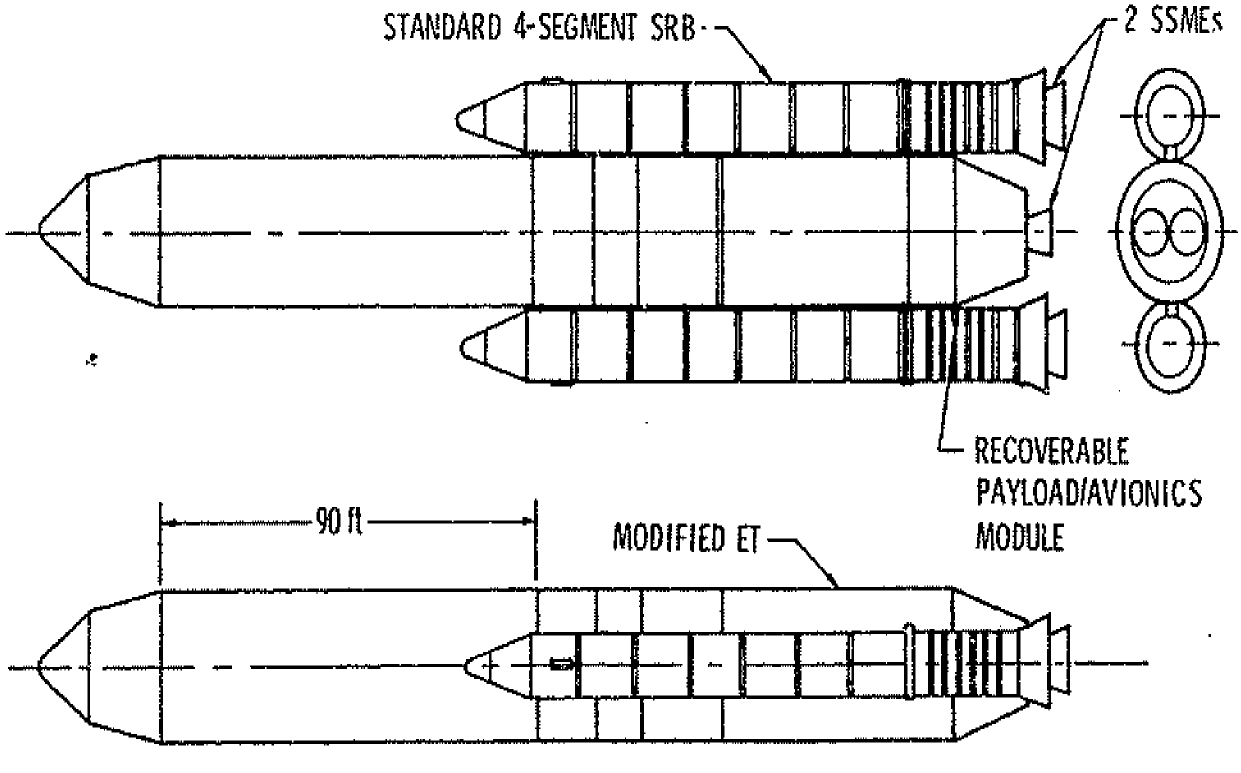


FIGURE II-1

Reference Side-Mount ULV Configuration

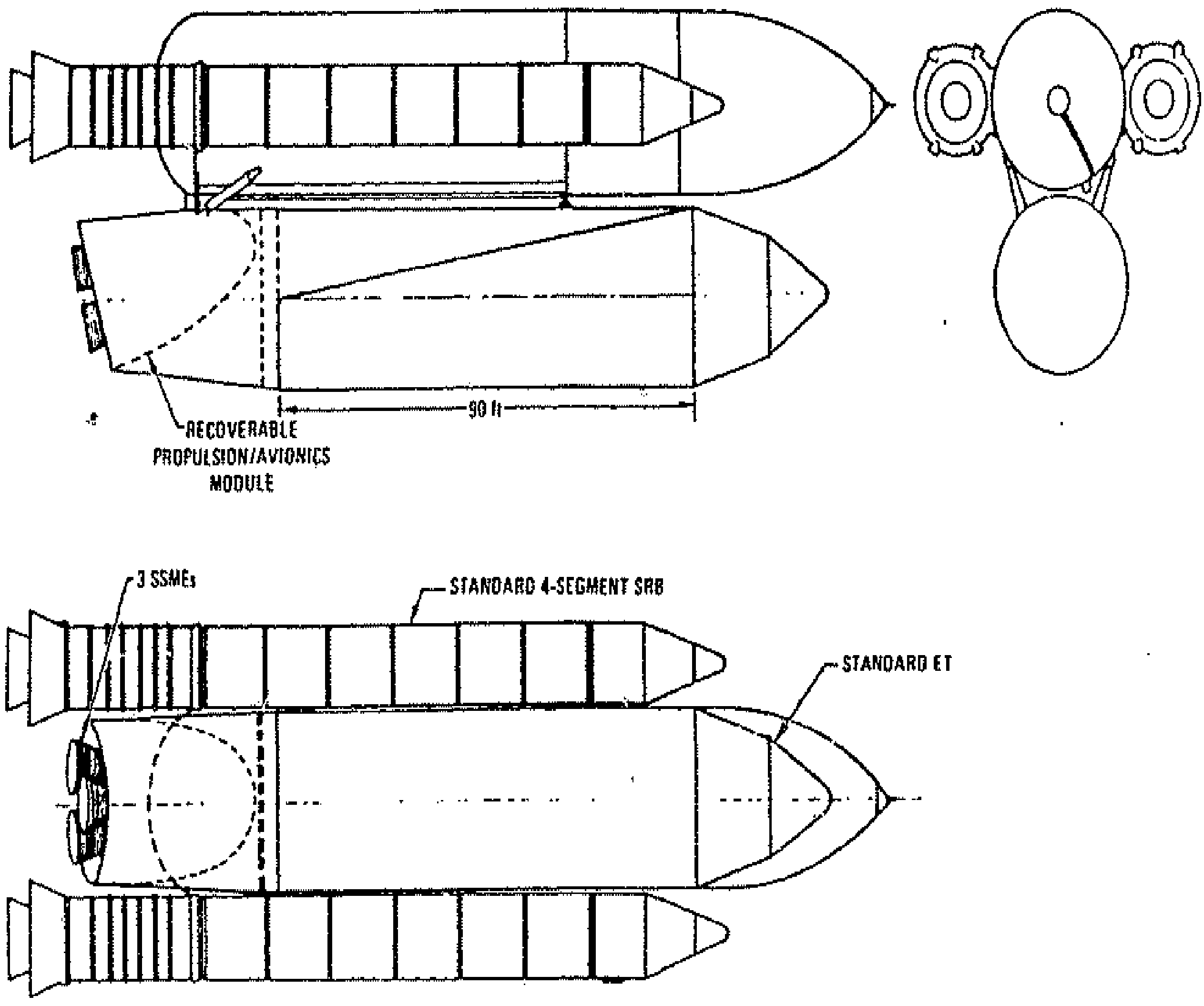


FIGURE II-7

A standard Shuttle External Tank (ET).

A payload module, mounted in place of the Shuttle orbiter, capable of carrying a 90 foot x 25 foot payload.

Both configurations utilize a recoverable propulsion/avionics module for the recovery of the high value hardware, such as the engines and avionics. Recovery of this hardware is believed to be cost-effective regardless of the vehicle configuration. Both ballistic reentry and lifting-body technologies are being considered for de-orbit, re-entry, and recovery of the propulsion/avionics module. Conceptual sketches of both propulsion/avionics module configurations are shown in Figures II-3 and II-4.

The preferred landing location for the propulsion/avionics module is on land, possibly at White Sands Missile Range or Edwards Air Force Base. Water landing has also been considered and detailed trade studies will be performed prior to the selection of a recovery concept.

In-Line Propulsion/Avionics Module Configuration

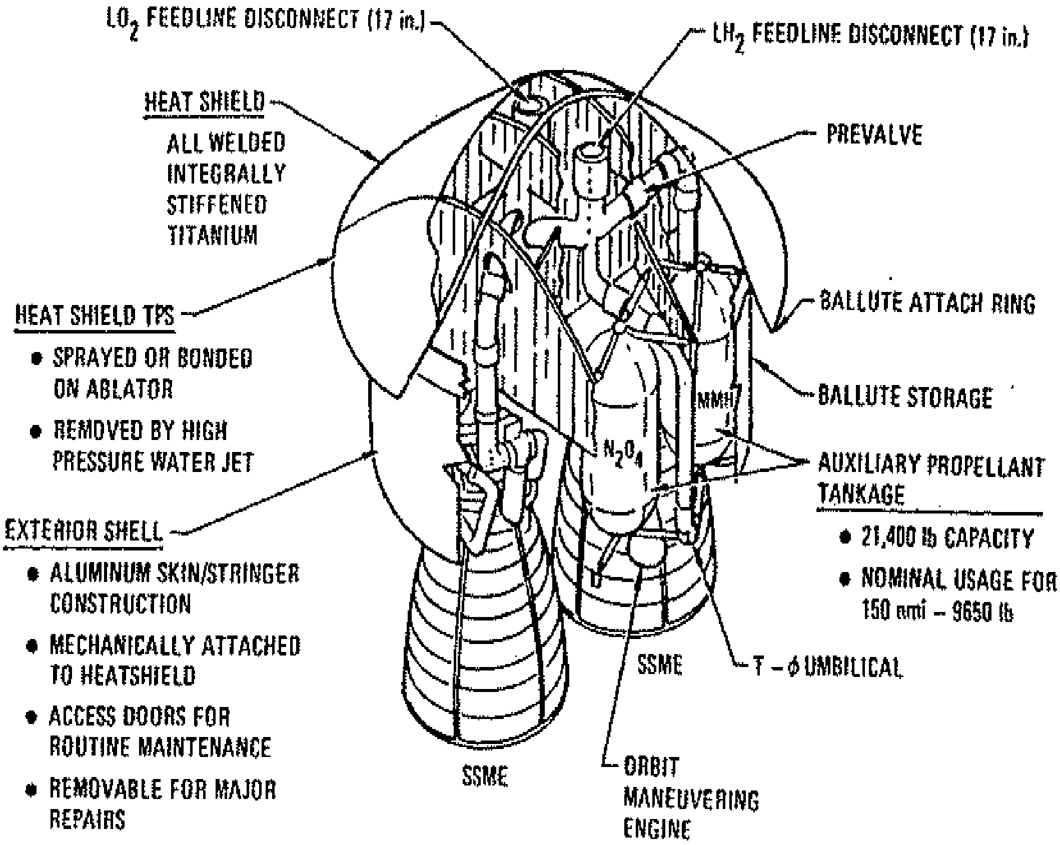
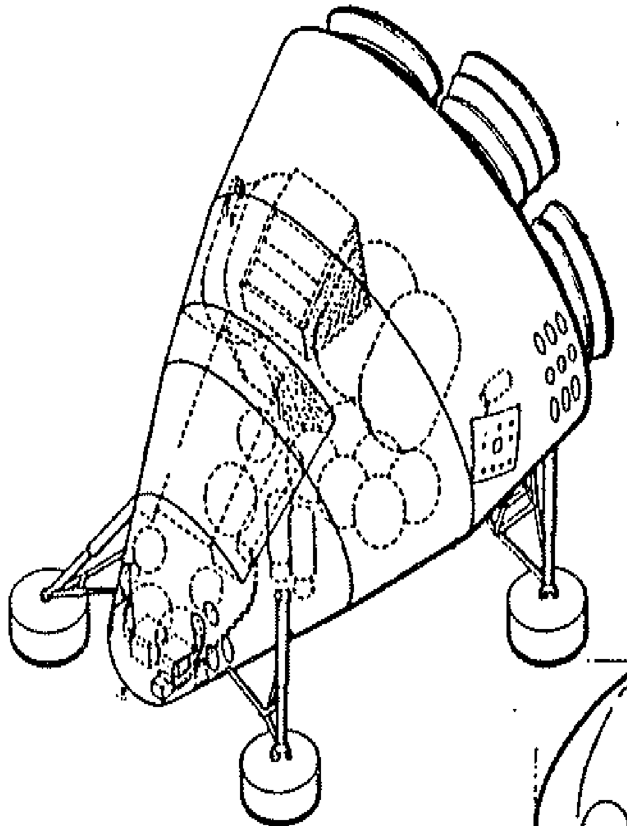
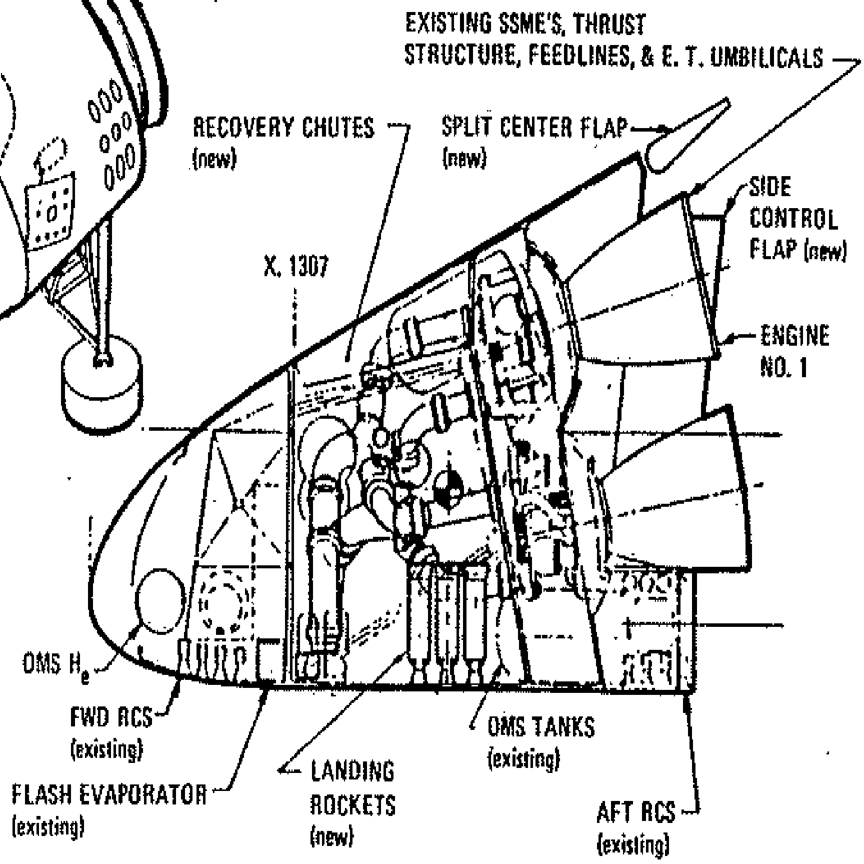


FIGURE 11-3

Side - Mount Propulsion / Avionics Module Configuration





INBOARD PROFILE

FIGURE II-4

III PERFORMANCE

The predicted typical perf

configurations shown in Figures II-1 and I

Low Earth Orbit (LEO)

KSC

VAFB

Geosynchronous Orbit (GEO)

KSC

VAFB

III PERFORMANCE

The predicted typical performance in pounds for the vehicle configurations shown in Figures II-1 and II-2 is approximately:

	2-SSME In-Line	3-SSME Side-Mount
Low Earth Orbit (LEO)		
KSC	145,000	160,000
VAFB	110,000	125,000
Geosynchronous Orbit (GEO)		
KSC	30,000	32,000
VAFB	15,000	17,000

IV FACILITIES AND GROUND PROCESSING

To the maximum extent feasible, existing Space Shuttle facilities at both Kennedy Space Center (KSC) and Vandenberg AFB (VAFB) would be used to process and launch the Unmanned Launch Vehicle. With either vehicle configuration, the Solid Rocket Boosters and External Tank operations would be similar to those procedures used for processing the Space Shuttle. Major facility modifications for processing these elements are not anticipated, however some modifications to the launch pads will be required at both launch sites. The exact nature of these modifications is vehicle configuration dependent and trade studies are needed to evaluate impacts of various vehicle designs on facility modification costs.

New facilities for assembling and integrating payloads, upper stages, and propulsion/avionics modules are needed at both KSC and VAFB. Cargo (or payload) dimensions will be much greater than those accommodated in the STS program, thus existing payload facilities will be inadequate. The new payload facility must have checkout and integration cells capable of servicing payloads on the order of 25 feet in diameter by 90 feet long.

V PROGRAMMATICS

A. Schedule

A development schedule for a ULV is shown in Figure V-1. The schedule outlines a success oriented program which leads to a first flight in late FY93. This Initial Launch Capability (ILC) is based on a conceptual design effort starting in FY84, with concept selection by FY87. Preliminary design would begin in FY88, leading to full scale development by FY89. This schedule was developed utilizing contractor data taken from NASA Shuttle derived vehicle studies.

B. ULV Contractual Activities

Funded cost refinement studies are currently on-going and will provide information to DOD on a wide range of system costs, including costs of design, development, test, facility modifications, and operations. Data from these studies will be used to support the Air Force FY86 BES and FY87 POM. Following these cost refinement studies, concept exploration studies are planned. These will be competitive studies and will probably be awarded to three or four contractors. These studies will focus on three major areas: ULV concept design, ULV impacts to existing launch facilities and ground operations, and more refined ULV cost estimates.

While these contractor concept exploration studies are in progress, a parallel Air Force study will define ULV system requirements and criteria for evaluation of contractor outputs. These requirements and criteria will be used in the ULV concept definition trade studies and support the final ULV concept selection.

Military Uses of Space: 1946-1991

Published by:
Chadwyck-Healey Inc., 1101 King Street, Alexandria, Virginia 22314

Military Uses of Space: 1946-1991 provides a detailed record of the strategic importance of the U.S. military space program from the conceptualization of the uses of space to the present realization of advanced capabilities. Materials were identified, obtained, assembled, and indexed by the National Security Archive, a non-profit, Washington, D.C. based research institute and library. The microfiche collection is accompanied by Military Uses of Space: 1946-1991 Guide and Index.

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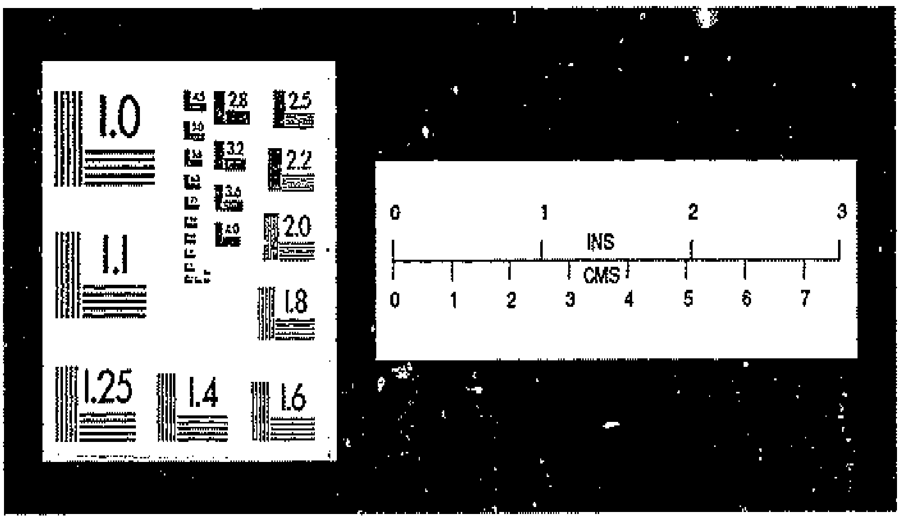

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ULV Development Schedule

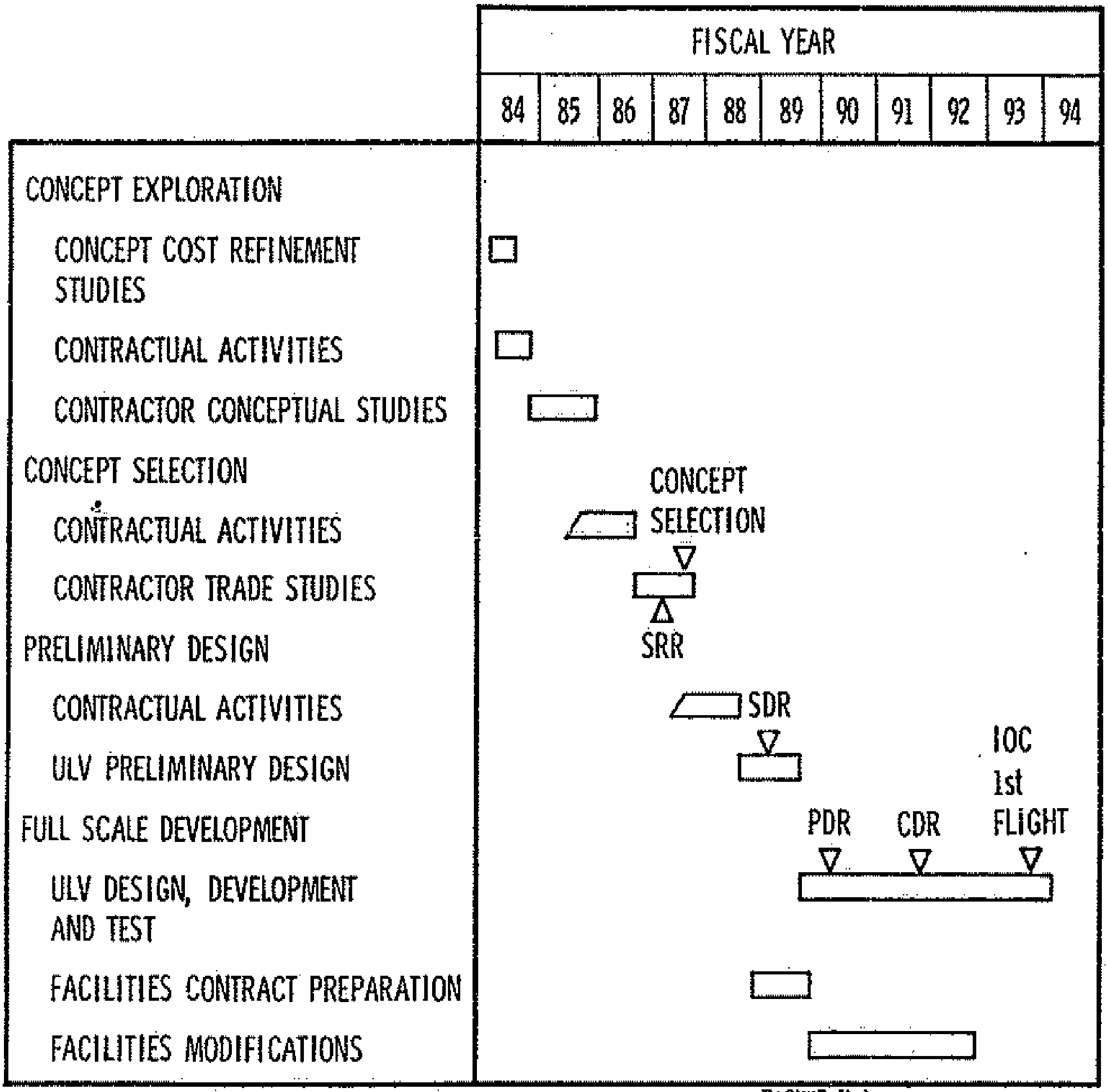


FIGURE V-1

C Program Costs

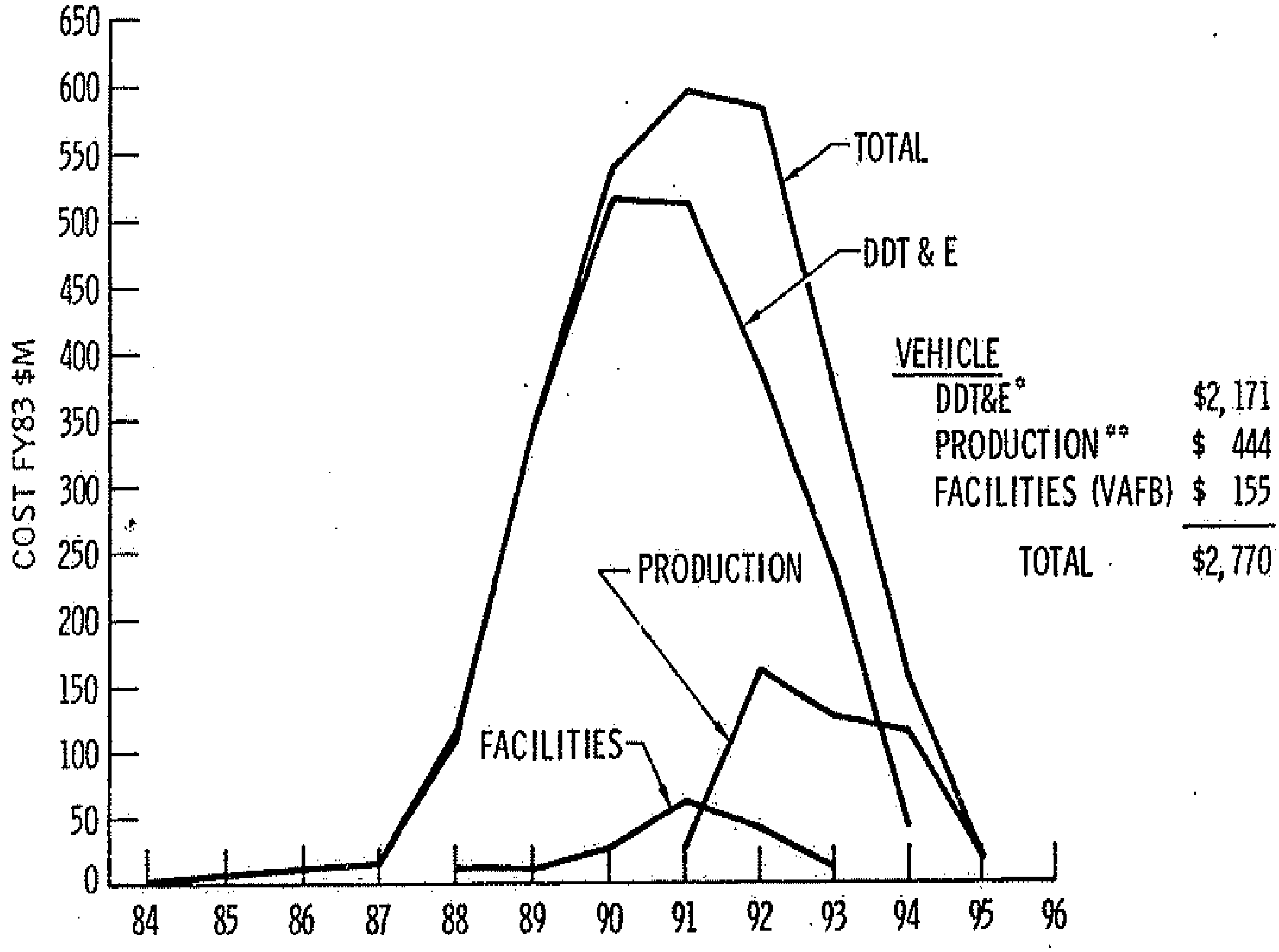
The complete ULV program cost has been preliminarily estimated at $2.8 billion. This includes $2.2 billion for design, development, test and evaluation (DDT&E), $450 million for production, and $150 million for modifications and additions to facilities at VAFB. These costs are spread over a nine year development and production program with the greatest peak year funding of $600 million in 1991 (Figure V-2).

Estimates for both the non-recurring and recurring costs of the ULV concepts were derived from the application of cost-estimating relationships based on cost histories of previous launch vehicles, including the Shuttle. In addition to these relationships, the actual cost of Shuttle system components was used as a basis for cost estimating whenever such components were included in a design.

All ULV cost estimates presented here are preliminary in nature and based on a side-mounted ULV reference configuration. The in-line configuration non-recurring costs (DDT&E, production, and facilities) are expected to be similar and roughly equal to the side-mounted configuration costs. The costs of DDT&E for the in-line and side-mount configurations are similar. Production of propulsion/avionics modules for the in-line configuration should be slightly cheaper due primarily to the two-SSME designs. Facility costs for the in-line configuration could be greater due to the need for greater modifications to the Shuttle launch pads. Some of these pad modifications could be avoided by operations scenarios such as air-starting the SSMEs. The concept cost refinement studies currently being conducted by the Air Force will provide a greater depth of detail and fidelity to cost estimates for both ULV reference configurations.

The DDT&E cost estimate of $2.2 billion FY83 dollars is primarily for the development of the propulsion/avionics and payload modules, with a lesser amount (about $10 million) for installing fixed de-orbit rockets on the External Tank. The propulsion/avionics module is considered to be the major development element, and is estimated to cost $1.9 billion FY83 dollars. The payload module development is estimated at $220 million. The DDT&E cost estimates include ground support equipment (GSE), limited spares, test units, Government support, and the SSMEs and avionics software required for the propulsion/avionics module. The test units built for DDT&E include two propulsion/avionics and two payload modules which will be used for the first

ULV Program Costs



* INCLUDES 2 P/A MODULES

** INCLUDES 1 P/A MODULE + SPARES

FIGURE V-2

two flights, after which the propulsion/avionics modules will be refurbished and used as operational modules.

ULV operations costs are scenario dependent and are effected by such variables as overall flight rate, launch site, and Shuttle versus ULV flight mix. In general, however, it is predicted that under any scenario, the ULV operations cost per flight will be in the range of 10% to 15% less than that of the Space Shuttle, with a substantial reduction in the cost per pound of payload.

VI GROWTH POTENTIAL

The ULV system is envisioned as a departure point for vehicles with heavier lift capability if the need develops. Potential ULV performance growth paths are illustrated in Figure VI-1. Several potential growth paths exist : 1) develop a liquid rocket booster (LRB) to replace the baseline SRBs, 2) to increase the dimensions of the ET and number of SSMEs, and 3) increase the number of SRB segments. Any of these approaches would necessitate extensive launch facility modifications. It is evident that there are points in the ULV payload capacity growth paths where revolutionary, rather than evolutionary, changes are needed to increase performance. Approximately 200,000 pounds to low earth orbit for instance, appears to be a plateau. System cost-effectiveness studies are needed to identify the proper solutions to greater weight-to-orbit requirements.

Potential ULV Evolution

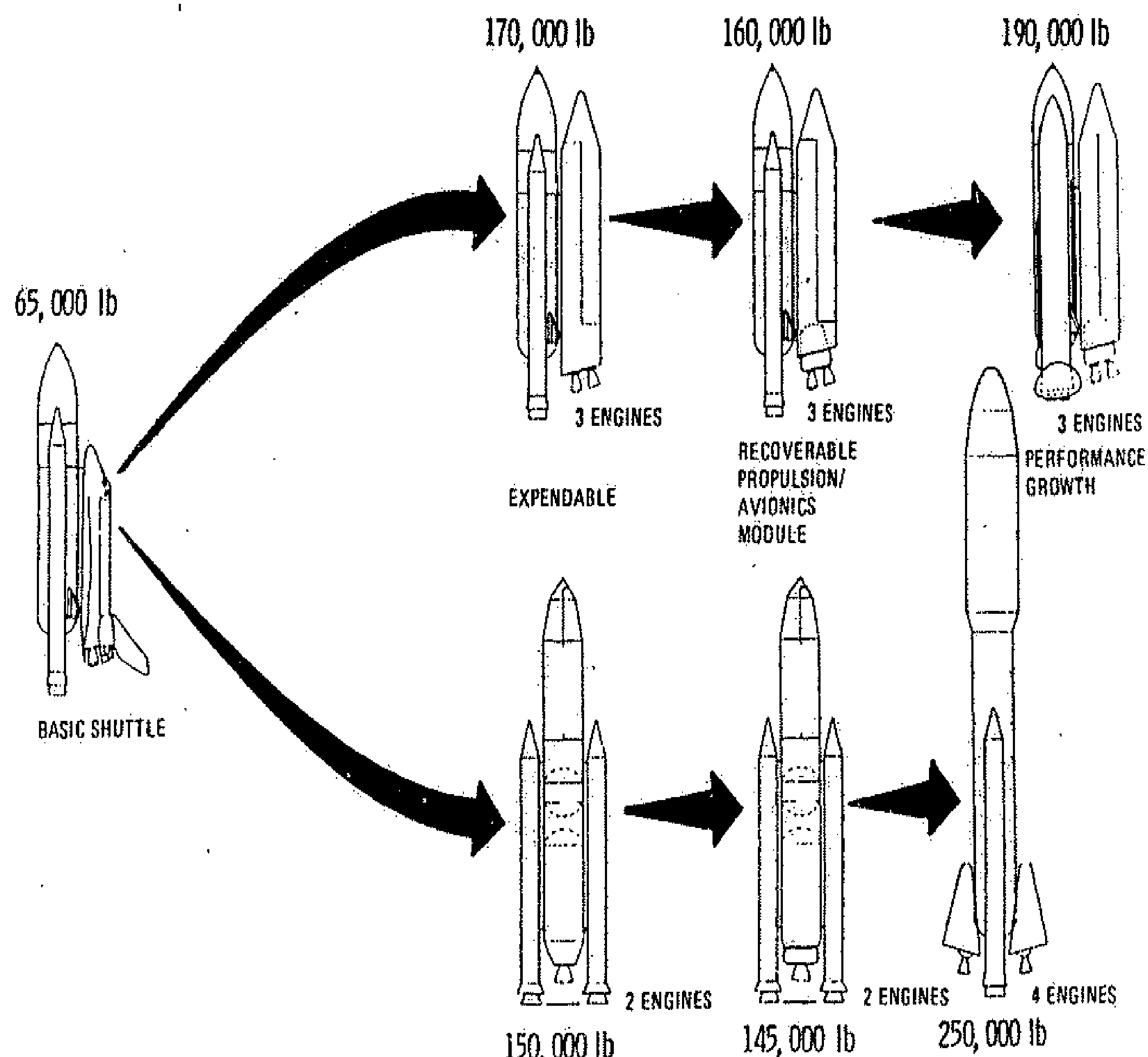


FIGURE VI-1

VII SUMMARY

To satisfy the potential requirement to place large DOD payloads into orbit in the mid-1990s and beyond, a much larger class of vehicle than the Space Shuttle is required. In order to satisfy these projected needs, the lowest risk and most cost effective approach appears to be that of developing a vehicle derived from Space Shuttle components. Such a vehicle would be capable of placing up to 200,000 pounds into low earth orbit.

History shows that DOD payload requirements typically push the performance limits of all available launch systems. With DOD requirements being the driving force for large space launch vehicles, logic dictates that DOD should develop, acquire, and operate these launch vehicles.

In support of the Secretary of Defense's policy regarding assured access to space, the Air Force must continue its studies defining large launch vehicle concepts for the mid 1990's and plan for their acquisition.

APPENDIX

I INTRODUCTION

A. Background

The potential need for heavier DOD payloads beyond the capability of the current Shuttle has aroused DOD interest in Shuttle-derived Unmanned Launch Vehicles (ULVs) with payload capabilities of two to three times the capability of the Shuttle. During the past ten years heavy lift launch vehicles, including Shuttle-derived versions, have been examined in a series of studies by NASA for a number of applications. However, it is only recently that a DOD need for such a vehicle has been envisioned and only very limited DOD resources have been expended on studying heavy lift launch systems. Some Shuttle improvements are possible. However, it is not cost-effective to increase the Shuttle orbiter payload bay dimensions from the present 15 feet diameter by 60 feet, or to increase the nominal payload capability of 65,000 pounds to low earth orbit (LEO) from KSC by more than about 10,000 to 15,000 pounds. The projected DOD transportation needs postulated for the mid- to late-1990s will considerably exceed the capability of the Shuttle or any feasible uprated or improved Shuttle. A secondary reason to consider a Shuttle-derived ULV is that it could provide single-site launch capability (out of VAFB) for all presently approved and envisioned DOD payloads. In summary, the major reasons for developing a DOD Shuttle-derived ULV are as follows:

1. Use of current flight-proven Shuttle components minimizes development risk.

2. The payload capability of the Shuttle can be more than doubled with a graceful, flexible, and low risk growth path to three or four times current shuttle payload capability.

3. The present payload volume can be greatly increased.

4. Improved amortization of Shuttle hardware, processing facilities, and launch crews is provided.

5. The Shuttle component production base is maintained.

B. Previous Studies

Heavy-lift launch capability based on Shuttle components has been under examination for the last ten years. Heavy-lift launch vehicles using Shuttle-based technology were also studied as part of the various NASA/-DOE Solar Power Satellite (SPS) studies conducted in the period 1976 through 1981.

C. Definition

The ULV is defined as a vehicle which makes maximum cost-effective use of existing Space Shuttle technology and components, thus, providing for ULV options which have the capability to launch payloads much heavier than the current Shuttle. The major Shuttle components that are utilized are: the main engines (SSMEs), the solid rocket boosters (SRBs), and the external tank (ET). A ULV which utilizes two SSMEs will deliver nearly three times the current Shuttle payload. Many of the improvements proposed for the Shuttle (for instance, uprating the SSMEs or substituting liquid rocket boosters (LRBs) for the current SRBs) can be directly applied to the ULV.

For study convenience, the ULV configurations have been separated into two generic concepts: versions in which the payload and the SSMEs are installed in-line with the ET; and side-mount versions in which the payload and the SSMEs are installed in essentially the same geometrical relationship to the ET as the current Shuttle.

D. Goals/Guidelines

The ULV program is conceived as a DOD-controlled and managed development program which will support autonomous, secure DOD space operations in the mid-1990s. Depending on need, a growth version may later be developed to support more ambitious space operations early in the next century, and growth potential should be designed into the baseline system.

The ULV will not eliminate the need for the current Space Transportation System (STS), but will provide a complementary addition to it since it could be fully compatible with current and growth Shuttle payload interfaces. It will be compatible with STS facilities and operations at both KSC and VAFB, although, some launch facility modifications may be needed. The ULV is expected to make extensive use of VAFB STS facilities.

APPENDIX

II REQUIREMENTS

A. General

Projected DOD programs indicate the potential for payloads weighing in the range of 150,000 to 200,000 pounds and dimensions of 25 feet diameter x 90 feet long, or possibly more. In order to enhance secure operations for DOD missions, it is desirable to launch as many DOD payloads as possible from VAFB. In order to minimize the complexity associated with the launch of DOD payloads, it is envisioned that ground and flight operational procedures similar to those utilized by Expendable Launch Vehicles will be employed.

B. Payload

A set of preliminary reference payload requirements is delineated in the Classified Annex. Some large payloads could be assembled on orbit and; therefore, there is a need to examine the design of advanced payloads in consonance with the launch vehicles that may deploy them.

C. Operational

The major operational goals include the following:

1. Secure, independent DOD space operations from VAFB.

2. Complementary operations with the STS which extend the Shuttle Orbiter life and back up the STS in the event of Orbiter fleet grounding.

APPENDIX

III ULV CONCEPTS

A. Vehicle Description

1. In-Line

A typical in-line ULV is illustrated in Figure AIII-1 and has the following characteristics:

a. Payload Interface

A payload interface compatible with current and growth Shuttle missions.

b. Shuttle Components

The following Shuttle components are included:

Two standard SSMEs, installed in-line with the external tank, operating at 100% to 104% power level, and capable of being restarted and utilized for direct orbit insertion.

Two standard (steel case) SRBs.

A modified ET, sized to optimize performance.

c. Cargo Volume

A payload installation with the capacity to carry a 25 feet diameter x 90 feet long cargo.

d. Propulsion/Avionics Module

The recovery of the SSMEs, avionics and other high cost items in a recoverable propulsion/avionics (P/A) module using land recovery. Figure III-2 shows one proposed configuration for the in-line P/A module.

e. Mass Properties

The estimated gross liftoff weight is 3.9 million pounds.

2. Side-Mount

A typical side-mount ULV is illustrated in Figure AIII-3. It has the following characteristics:

a. Payload Interface

A payload interface compatible with current and projected versions of DOD missions planned for Shuttle flights.

Reference In-Line ULV Configuration

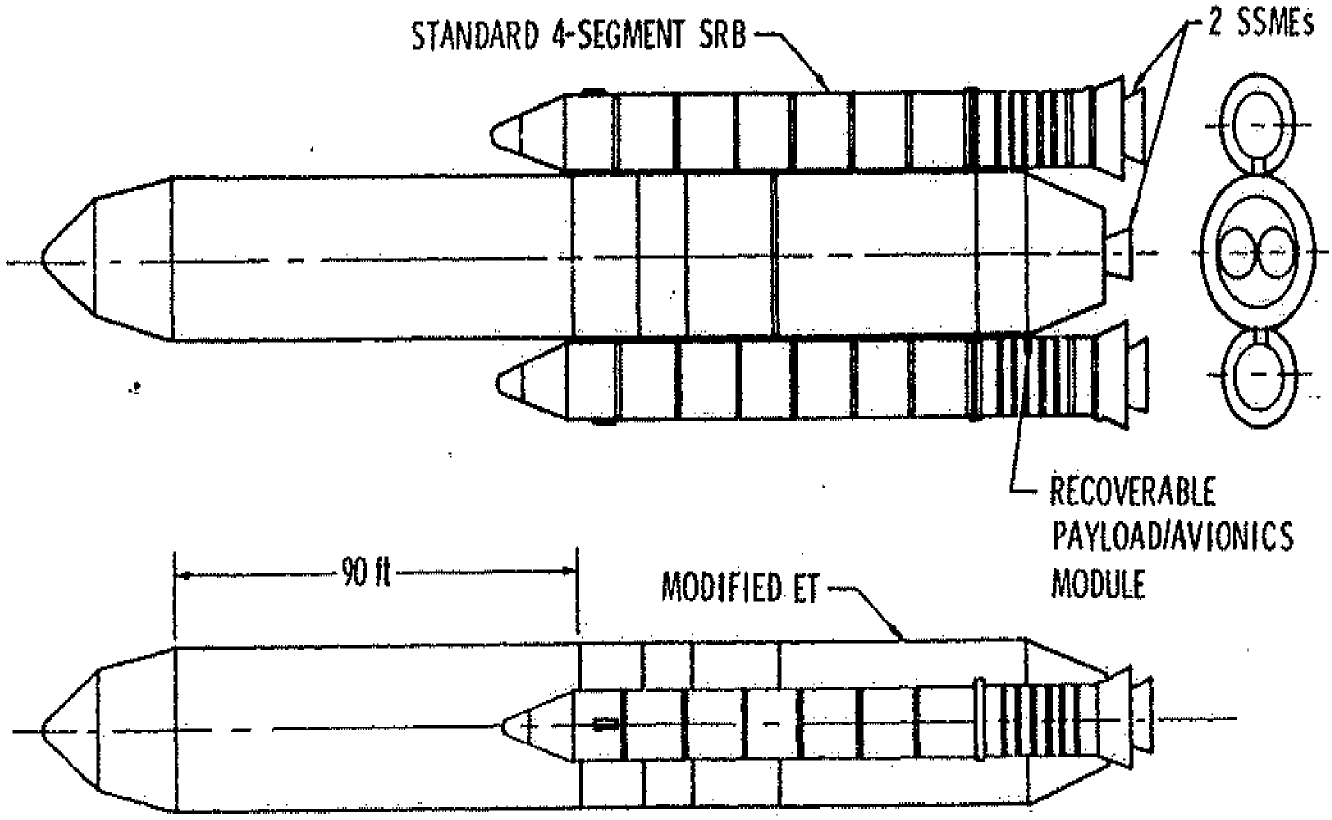


FIGURE AIII-1

In-Line Propulsion/Avionics Module Configuration

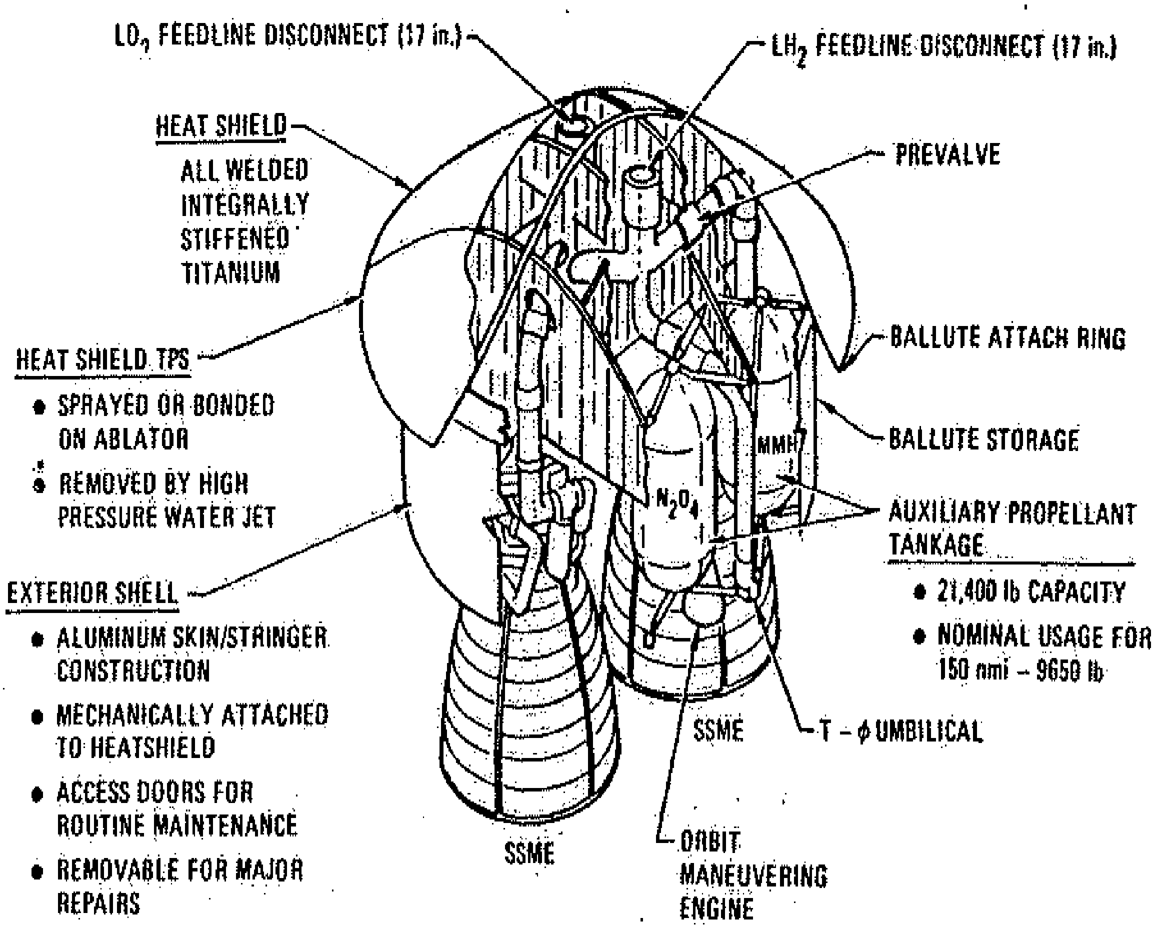


FIGURE AIII-2

Reference Side-Mount ULV Configuration

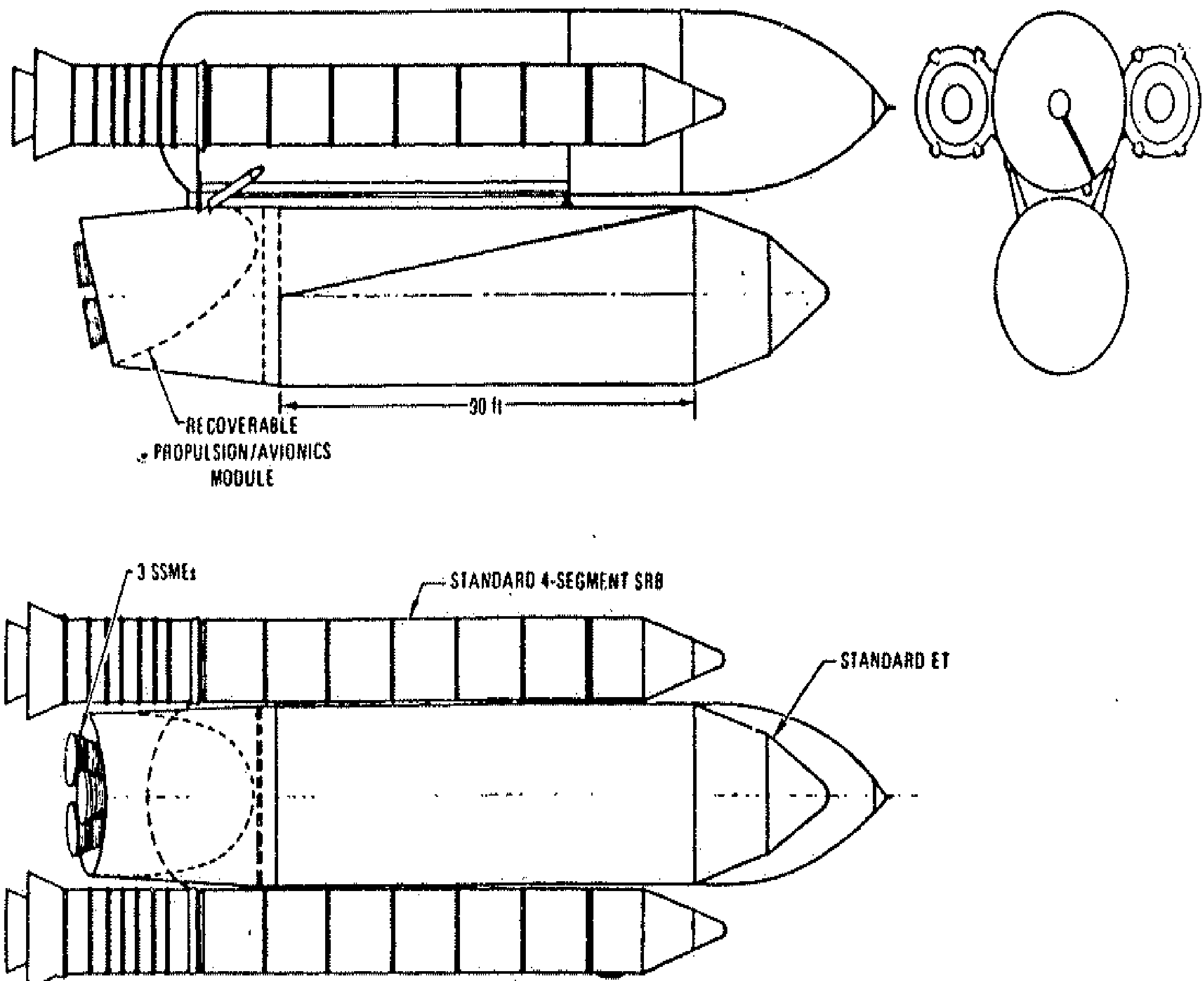


FIGURE AIII-3

b. Shuttle Components

The following Shuttle components are included:

Three standard SSMEs, side-mounted to the ET in a geometric relationship similar to the current Shuttle, operating at 100% to 104% power level, capable of being restarted and utilized for direct orbit insertion.

Two standard (steel case) SRBs.

A standard ET.

c. Cargo Volume

A side-mount payload installation with the capacity to carry a 25 feet diameter x 90 feet long cargo.

d. Propulsion/Avionics Module

The recovery of the SSMEs, avionics and other high cost items in a recoverable propulsion/avionics (P/A) module using land recovery. Figure AIII-4 shows one proposed configuration for the side-mount P/A module.

e. Mass Properties

The estimated gross liftoff weight is 4.3 million pounds.

B. Mission Profile

A typical ULV mission profile is shown in Figure AIII-5. It consists of the following operations:

1. Launch and Ascent

The vehicle is launched from an essentially unchanged STS launch pad since all standard exhaust ducts are utilized and the ULV gross lift-off weight is less than that of the Space Shuttle.

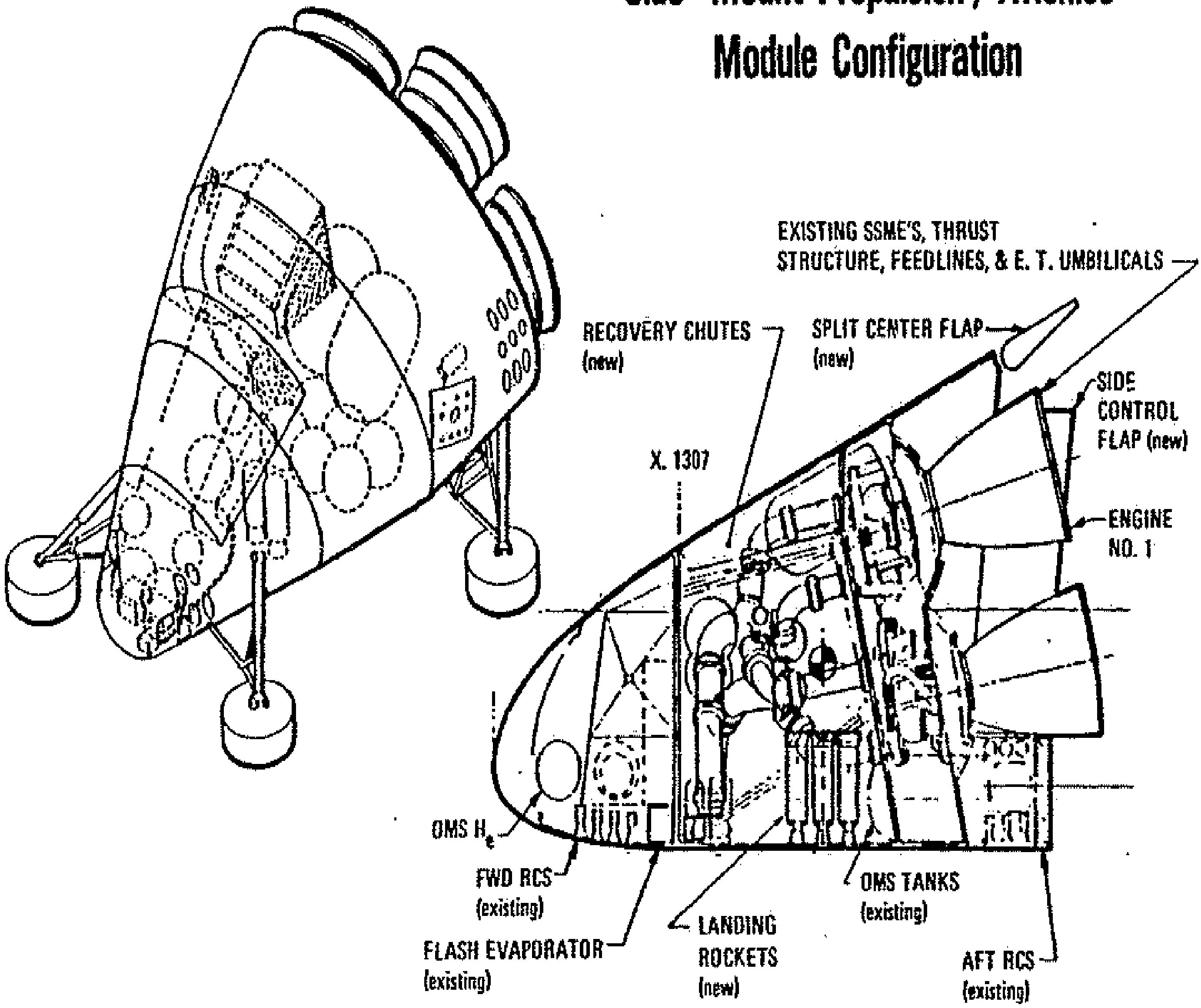
2. SRB Separation

The SRBs are separated and recovered as in the STS launch profile.

3. Payload Shroud Jettison

Approximately half of the payload (P/L) module, the non-load carrying shroud, is jettisoned shortly after separtion of the SRBs.

Side - Mount Propulsion / Avionics Module Configuration



INBOARD PROFILE
FIGURE AIII-4

Vehicle Mission Profile

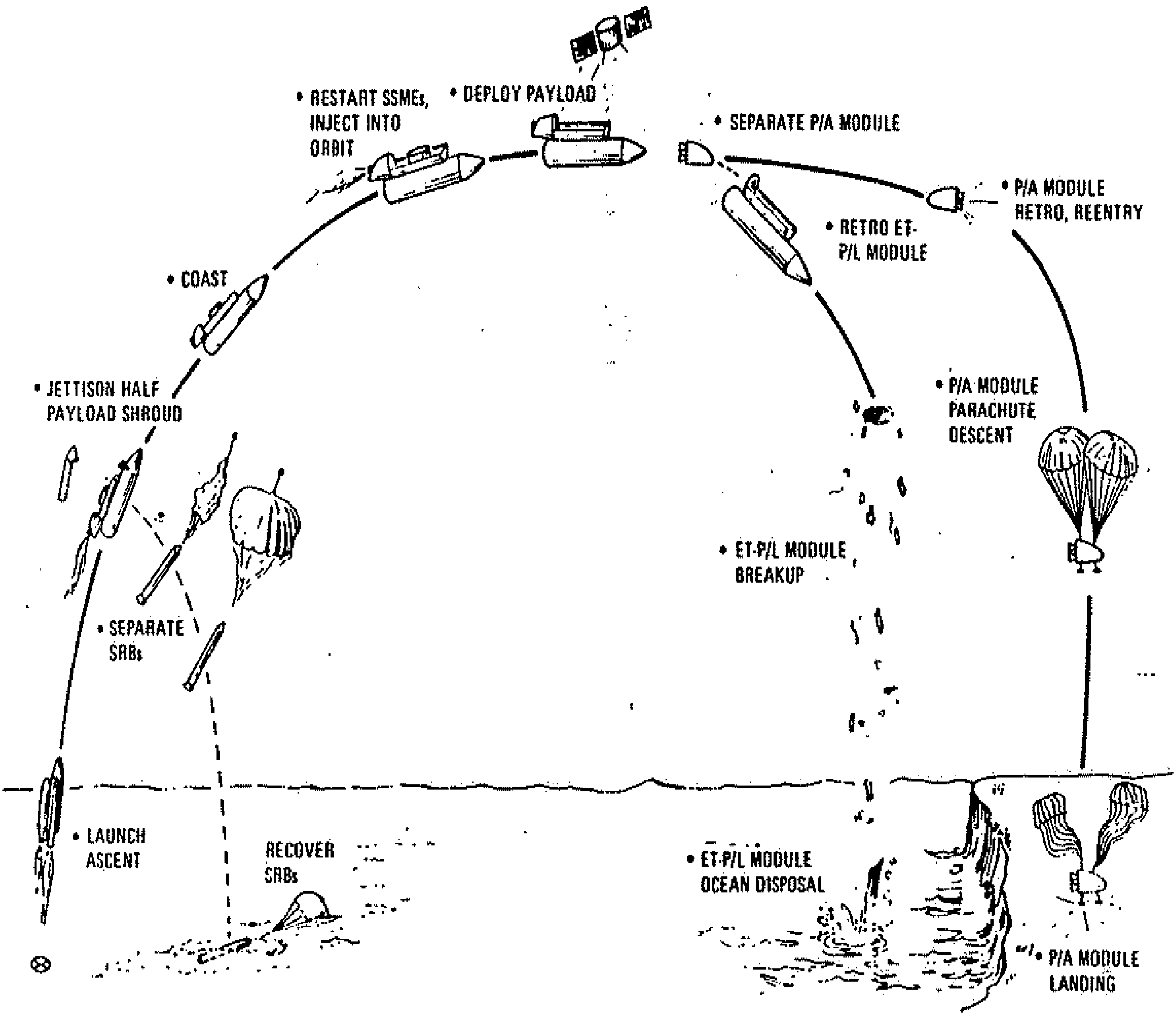


FIGURE AIII-5

4. Main Engine Cutoff (MECO) and Coast

The SSMEs are shut down in a similar way to the Shuttle procedure and the vehicle coasts to apogee.

5. Main Engine (SSME) Restart and Injection

The SSMEs are restarted and used to inject the vehicle into a park orbit, or final orbit, dependent on mission needs.

6. Payload Deployment

The payloads are deployed from the payload module in a manner similiar to the Shuttle.

7. Tank Orientation, Vehicle Separation and Reentry

The Propulsion/Avionics (P/A) module orients the vehicle (consisting of the empty ET, the P/A module, and the remaining structural half of the P/L module) in preparation for separation and reentry. The P/A module separates from the rest, leaving the ET and the P/L module in the correct position and attitude for firing small retro rockets. The ET together with the attached P/L module then reenters for destruction in a safe area; the P/A module stays in orbit until a suitable time for its controlled reentry.

8. Propulsion/Avionics Module Descent

The P/A module is deorbited and uses aerodynamic lift to descend in a controlled reentry mode.

9. Propulsion/Avionics Module Landing

A drag chute is deployed to slow the descent velocity prior to main parachute deployment and final descent to the landing area. The P/A module lands horizontally on skids or wheels at one of a number of possible land recovery sites.

C. Performance

1. In-Line

An in-line ULV will deploy 145,000 pounds to low earth orbit from KSC or 110,000 pounds from VAFB; or, using a Centaur G' upper stage, 30,000 pounds to geosynchronous orbit (GEO) from KSC and 15,000 pounds from VAFB. The performance from KSC is displayed parametrically in Figure AIII-6. This figure shows the low earth orbit performance from KSC as a function of orbital altitude and inclination. Figure AIII-7 shows comparable performance for flights from VAFB.

In-Line Reference Vehicle Payload Vs Orbit Altitude - KSC Launch

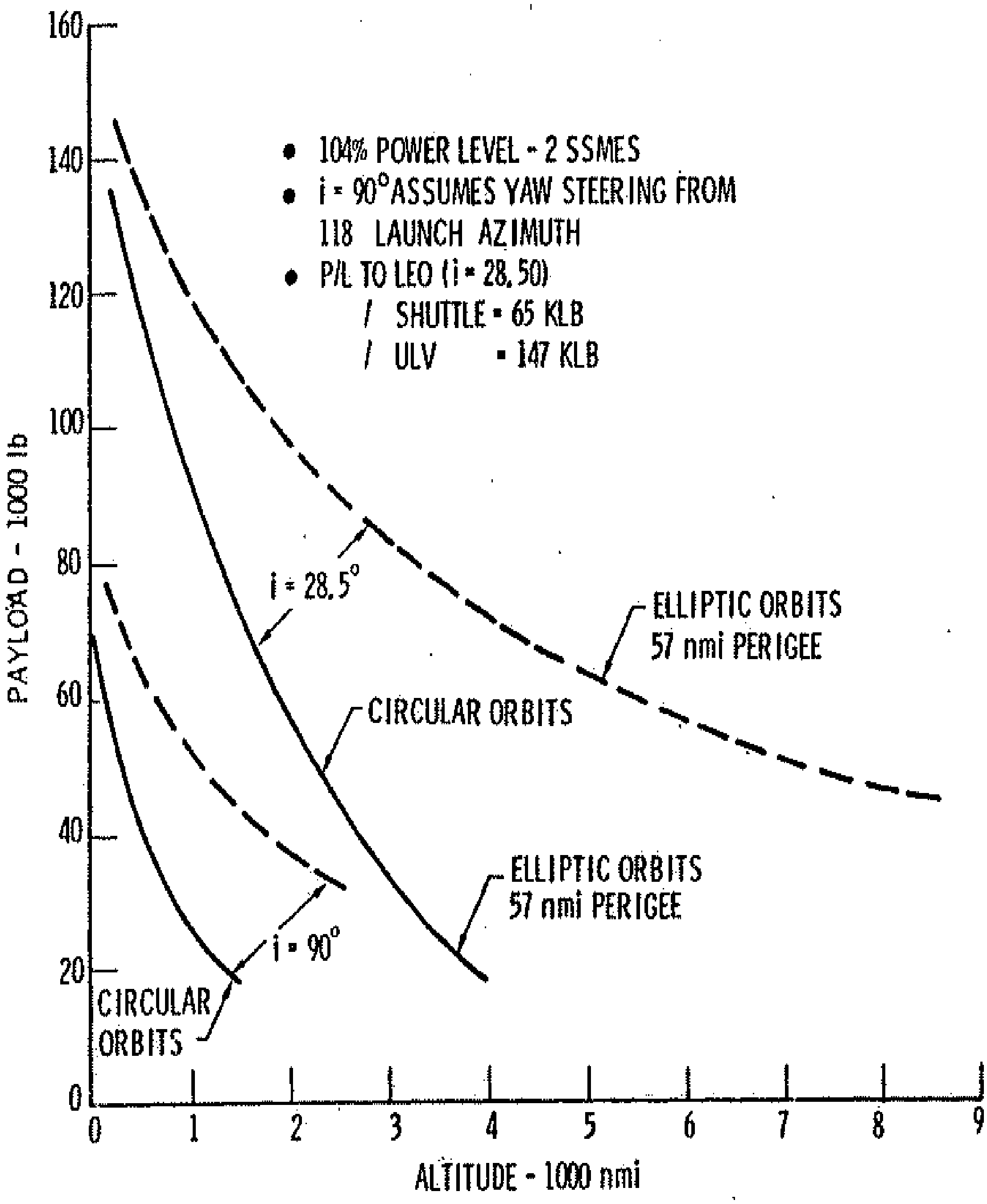


FIGURE AIII-6

In-Line Reference Vehicle Payload vs Orbit Altitude - VAFB Launch

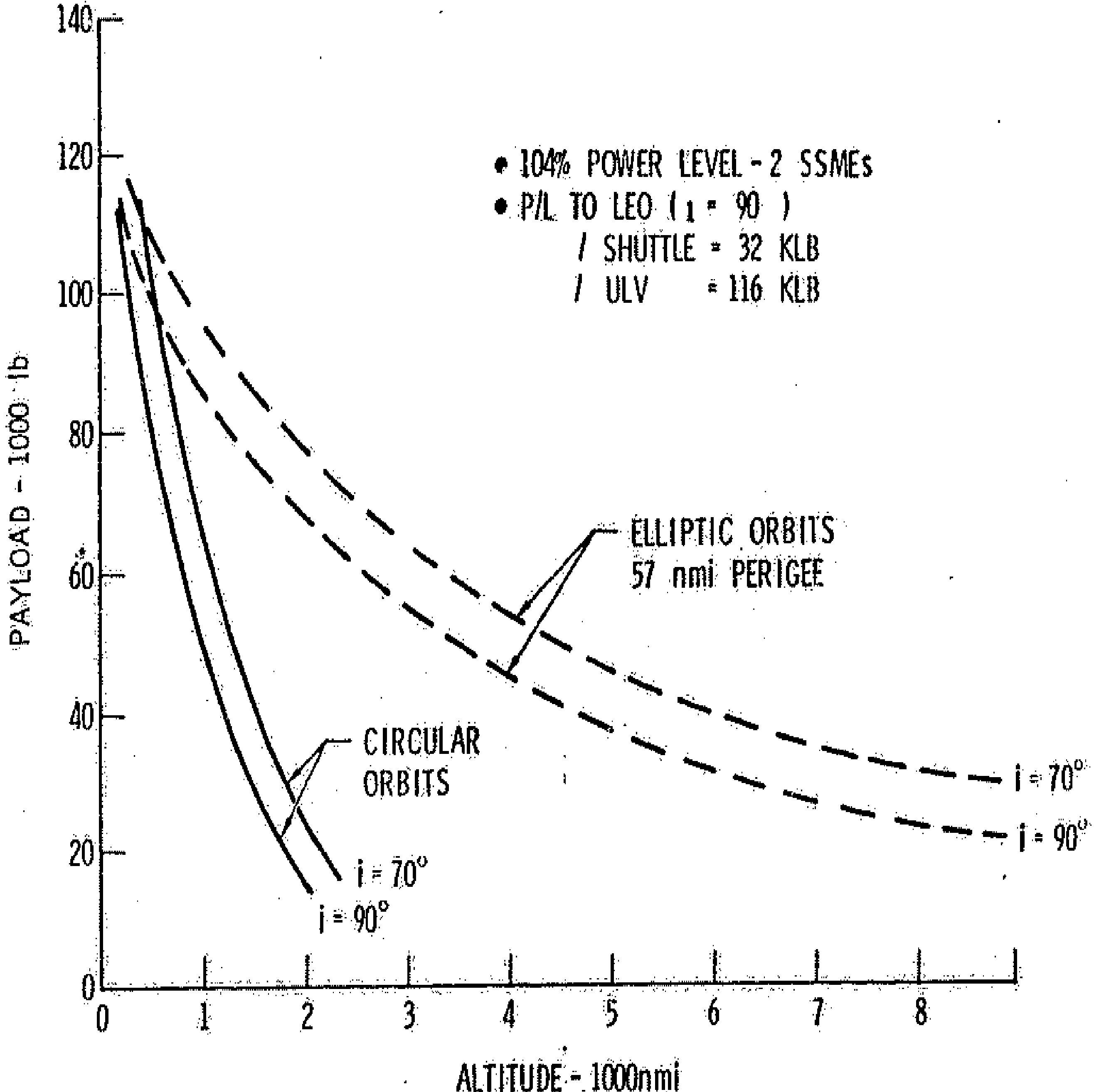


FIGURE AIII-7

2. Side-Mount

A side-mount ULV will deploy 160,000 pounds to low earth orbit from KSC or 125,000 pounds from VAFB; or, using a Centaur G' upper stage, 32,000 pounds to GEO from KSC and 17,000 pounds from VAFB. The performance from KSC is displayed parametrically in Figure AIII-8. Figure AIII-9 shows similar data for launch from VAFB.

D. Facilities and Ground Operations

The KSC ground operations flow for a typical ULV is illustrated in Figure AIII-10. The payload module is transported to KSC by barge from the manufacturer and moved into a new cargo module integration facility (CMIF). Individual payloads and upper stages are also moved into the CMIF. The payloads, upper stages and P/L module are integrated, checked out and made ready for transport to the vehicle assembly building (VAB) as an encapsulated element. The ET and SRBs are treated in an identical way to STS processing. The P/A module and P/L module assemblies are erected and mated to the ET. System integrated tests are performed on the vehicle and then it is moved to the launch pad by the mobile launch platform. The ULV is given pre-flight checks, loaded with propellants and launched.

The VAFB ground operations flow for a typical ULV is illustrated in Figure AIII-11. The P/L module is transported to VAFB by barge from the manufacturer and moved into the CMIF. Individual payloads and upper stages are also received at VAFB and moved into the CMIF. The payloads, upper stages, and P/L module are integrated, checked out and made ready for transport as an encapsulated element. The ET and SRBs are treated in an identical way to STS processing. At the launch area the SRBs are assembled and the ET is erected and mated using STS type procedures. The P/A module and P/L module assemblies are brought into the shuttle assembly building, erected, and mated to the ET. The ULV is given pre-flight checks, loaded with propellants and launched. Launch operations are controlled from the Launch Control Center (LCC) similar to the Shuttle.

New facilities for assembling and integrating payloads, upper stages, P/A modules and P/L modules are needed at both KSC and VAFB because cargo dimensions will be much greater than those accommodated in the STS program. The facility must have checkout and integration cells capable of servicing payloads greater than 25 feet in diameter and 90 feet long. Locations for support equipment must be provided. An airlock is required to provide for movement into and out of the facility.

New facilities for P/A module and upper stage checkout are needed at both KSC and VAFB. These may be an integral part of the CMIF or a comletely separate facility.

Side-Mount Reference Vehicle Payload vs Orbit Altitude

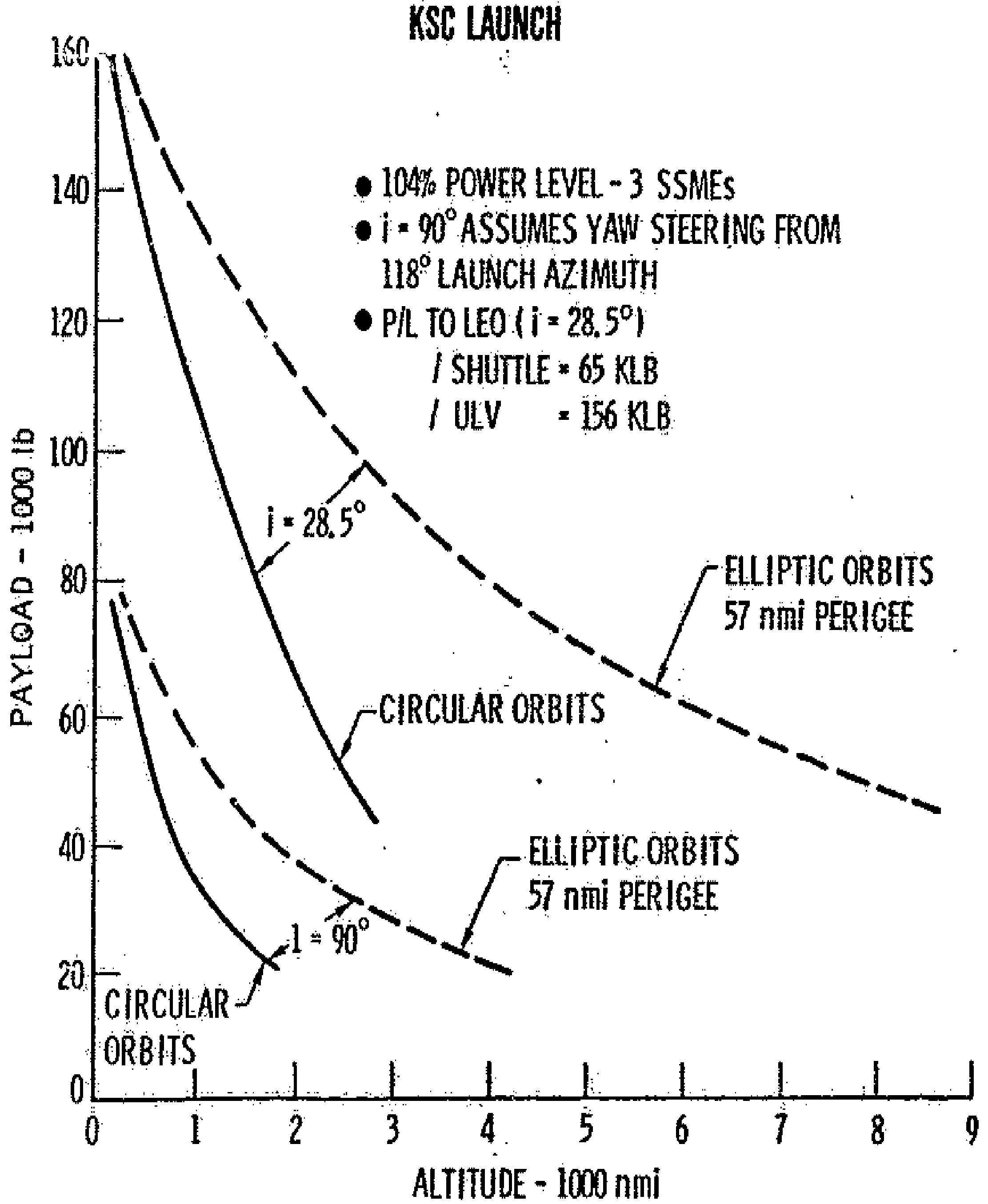


FIGURE AIII-8

Side-Mount Reference Vehicle Payload vs Orbit Altitude

VAFB LAUNCH

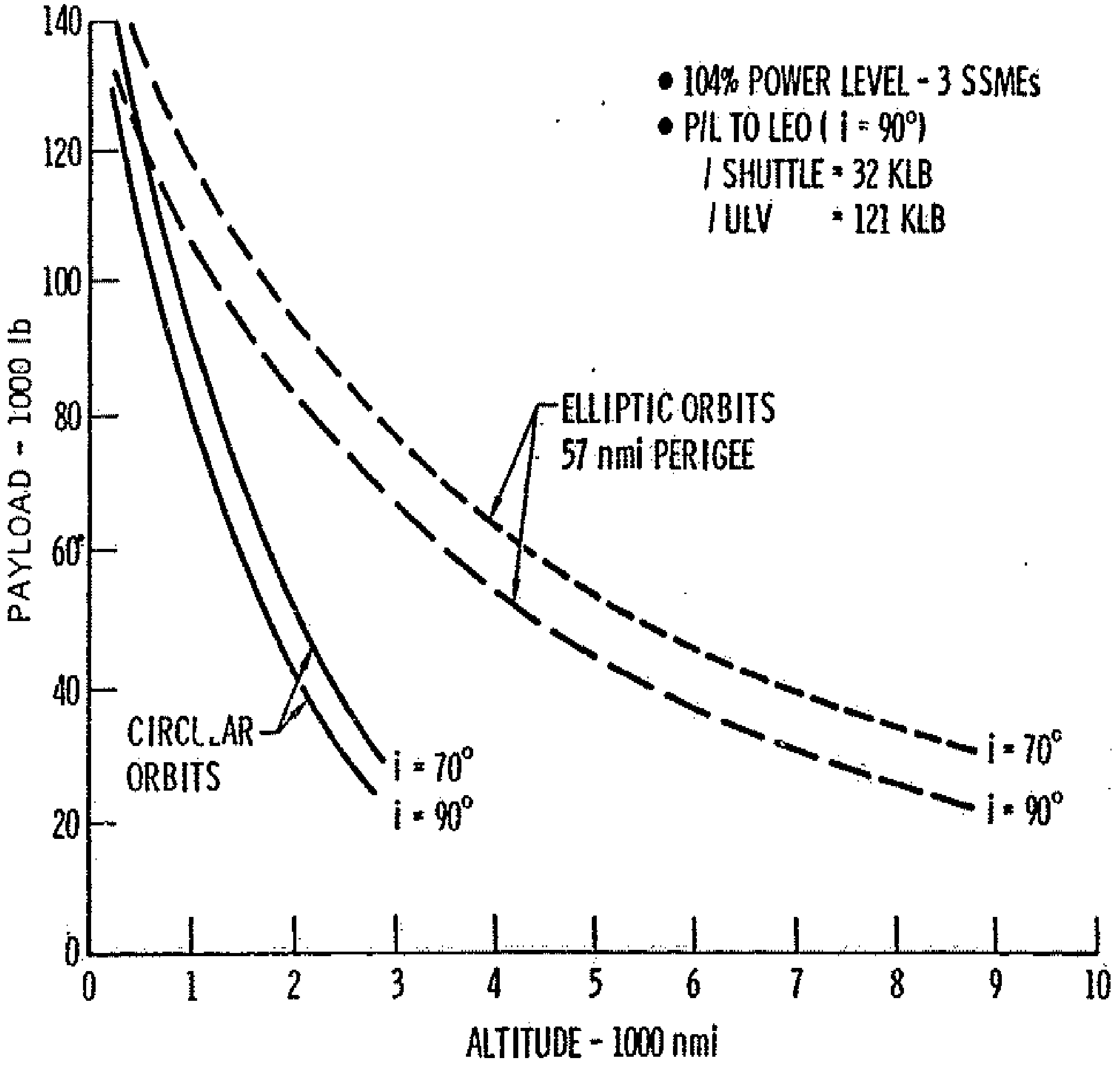
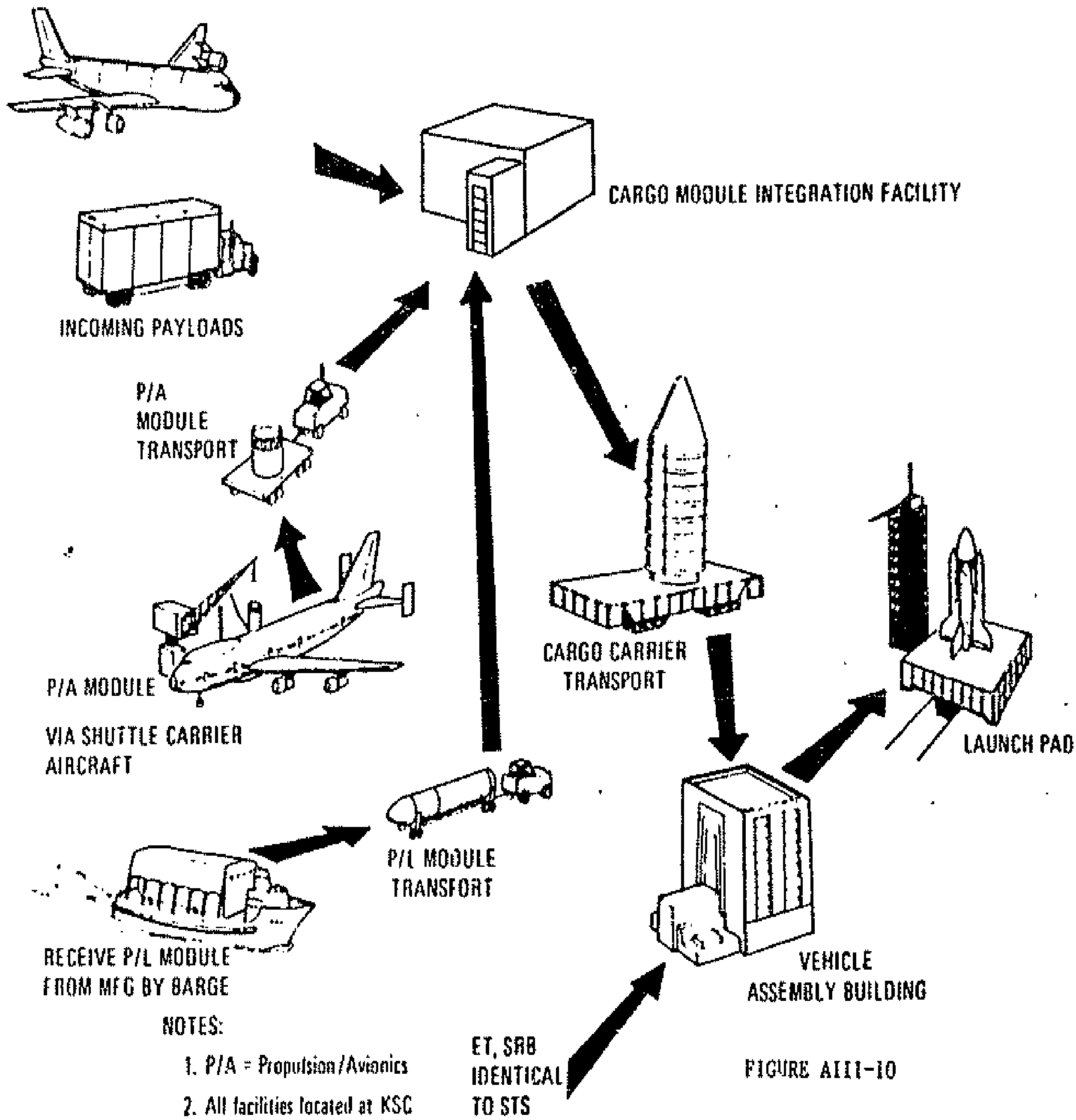


FIGURE AIII-9

System Ground Operations Flow at KSC



NOTES:

1. P/A = Propulsion/Avionics
2. All facilities located at KSC

FIGURE AIII-10

System Ground Operations Flow at VAFB

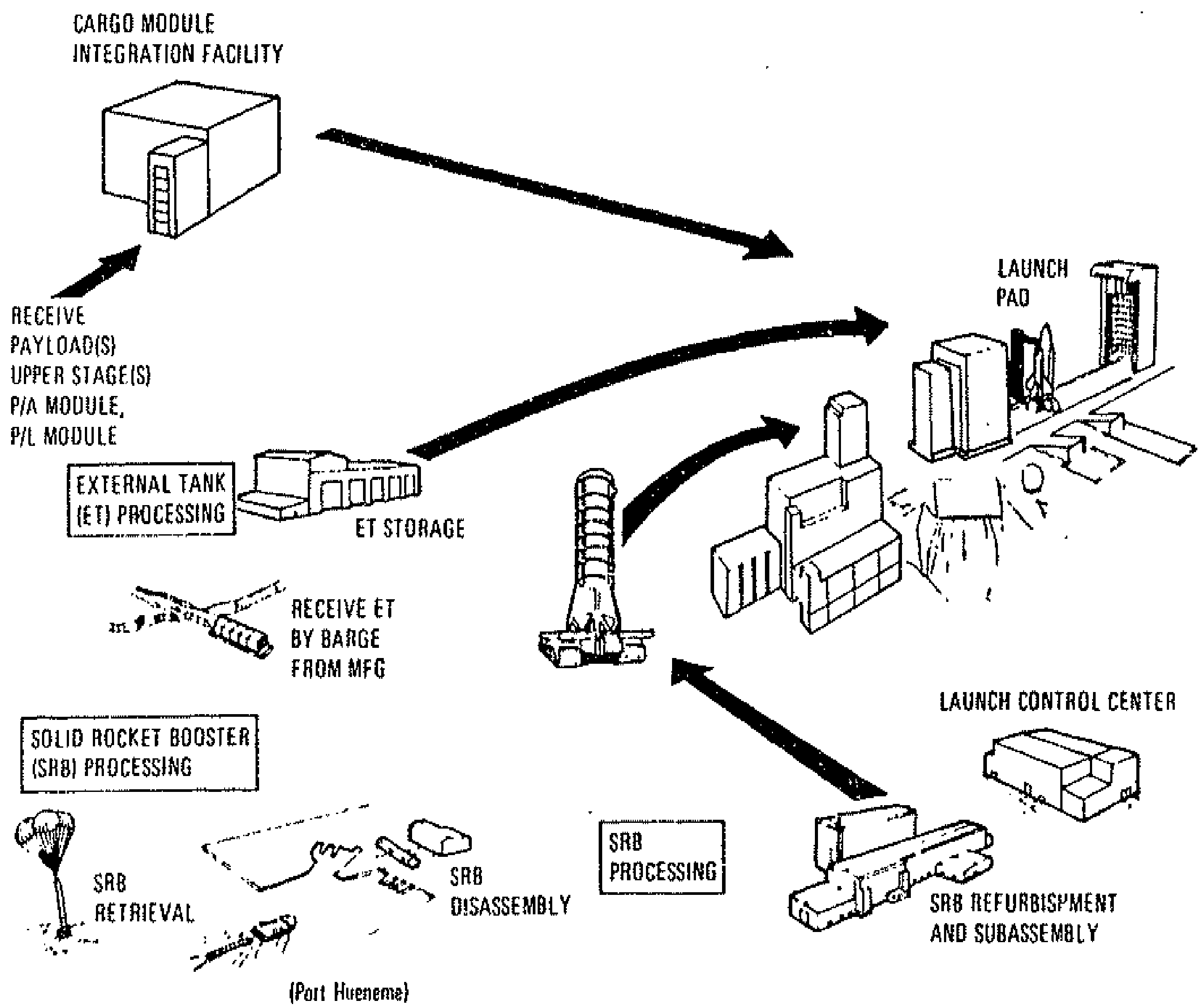


FIGURE AIII-11

APPENDIX

IV TECHNICAL ISSUES

A. General Discussion

Existing system concepts are based on NASA funded studies that have emphasized the use of STS hardware and facilities in establishing launch capabilities and system feasibility. DOD studies are needed to expand the data base to include system utility in a military operations environment and to permit convergence on the most promising concepts for satisfying DOD requirements early in the program. A number of critical issues must be resolved before a full-scale DOD commitment to the system can be made. Some of the major issues are discussed below.

B. In-Line vs Side-Mount

The in-line vehicle configurations, in general, provide higher performance and more scope to install the larger size P/L modules than the side-mount configurations. The side-mount configurations have greater Shuttle similarity, require less modification to the Shuttle elements that are being utilized, appear to impose the least facility impacts, and may result in the lowest acquisition costs. The choice between the in-line and side-mount design approach must be made at a later date.

C. Payload Accommodation and Deployment

The range of payload accommodation requirements, in terms of payload geometry, mass properties, interface requirements, environmental constraints, and support and deployment needs must be determined before selection of the final vehicle configuration.

D. Avionics

The avionics and power subsystem of transportation vehicles has historically represented a major cost element and; therefore, the issue of avionics system design must be resolved early.

10 February 1984

APPENDIX

V. TECHNICAL ISSUES

See Classified Annex

APPENDIX

VI PROGRAMMATICS

A. General Discussion

The principle ULV programmatic concerns are the development schedule, the ULV program costs and the ULV operations concept.

The present costs have been derived from in-house studies and NASA-funded contractor effort. However, a six month Concept Cost Refinement Study is currently underway to provide more accurate and refined cost analyses of two reference ULV concepts. The overall development has been preliminarily estimated as involving a nine year, $2.8 billion (FY83 dollars) effort.

B. Schedule

The ULV development schedule is shown in Figure AVI-1. The schedule outlines a success oriented program which leads to a first flight and ILC in late FY93. This ILC is based on a conceptual design effort starting in FY84, with concept selection in FY87. Engineering design would begin in FY88, leading to full scale development by FY89. The schedule was developed based on contractor estimates made for NASA Shuttle derived vehicle studies.

Figure AVI-2 contains a breakout of the near term Concept Exploration phase. The current cost refinement studies provide information on a wide range of system costs, including costs of DDT&E, facilities modifications, and the recurring costs of ULV operations. The study contractors will be the Martin Marietta Corporation and the Boeing Aerospace Corporation. Data from the studies will be used to support the Air Force FY86 BES and FY87 POM inputs. Following the Cost Refinement Study, a Concept Exploration Study is planned. This study will be done by competitive RFP and would probably include three or four contractors. The study would focus on three major areas: ULV concept design, ULV impacts to existing launch facilities and ground operations, and ULV cost estimates.

While these contractor concept exploration studies are in progress, a parallel USAF and Aerospace Corporation study will define ULV system requirements and evaluation criteria. These requirements and criteria would be used in the ULV concept definition trade studies and the final ULV concept selection (Figure AVI-3).

C. Program Costs

The complete ULV program cost has been estimated at $2.8 billion. This includes $2.2 billion for design, development, test and evaluation (DDT&E), approximately $450 million for production, and approximately $150 million for modifications and additions to facilities at VAFB. These costs in FY83 dollars are spread over a nine year development and production program with greatest peak year funding of approximately $600 million in 1991 (Figure AVI-4 and Figure AVI-5).

ULV Development Schedule

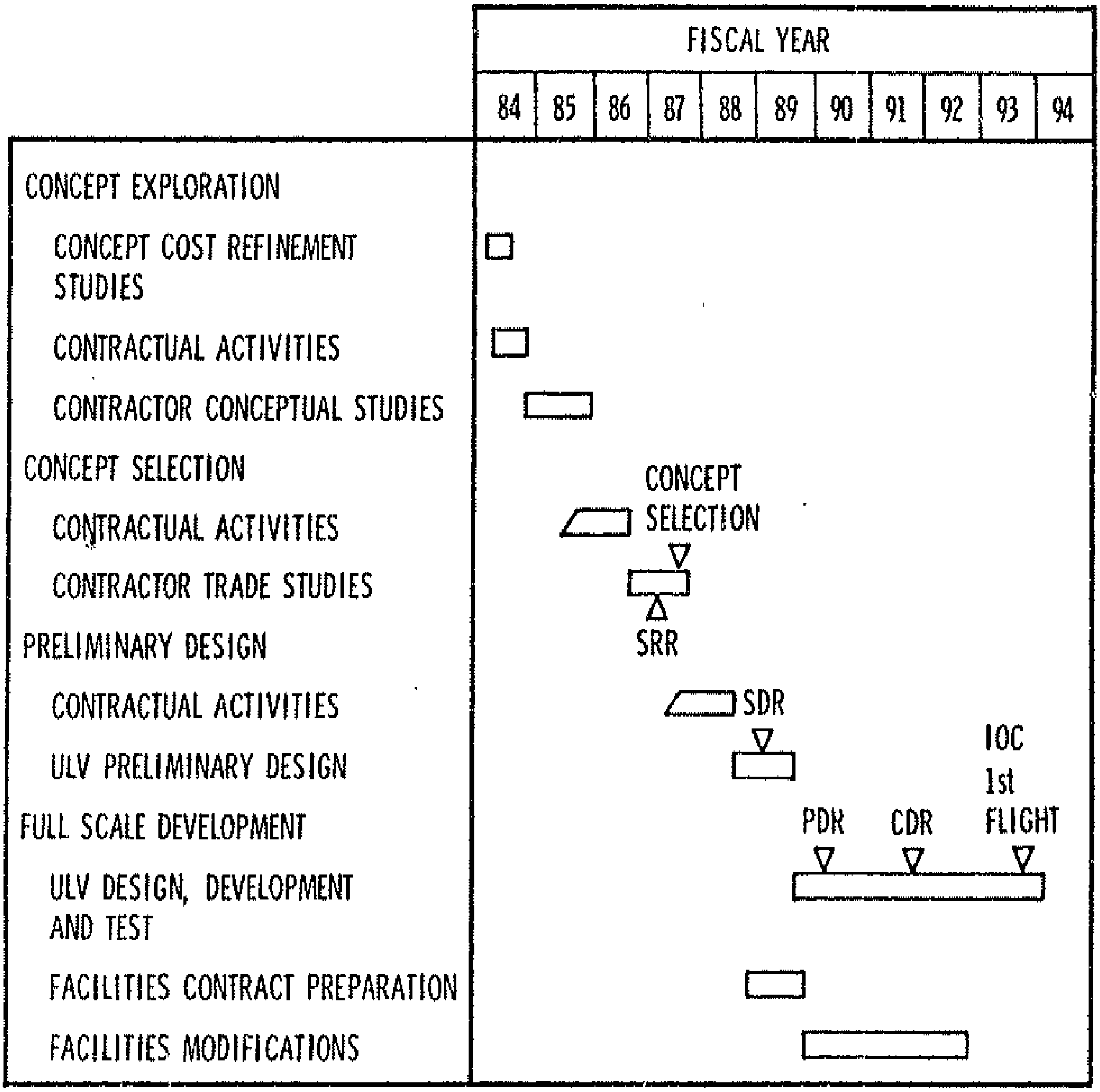


FIGURE AVI-1

ULV Development Schedule

CONCEPT EXPLORATION PHASE

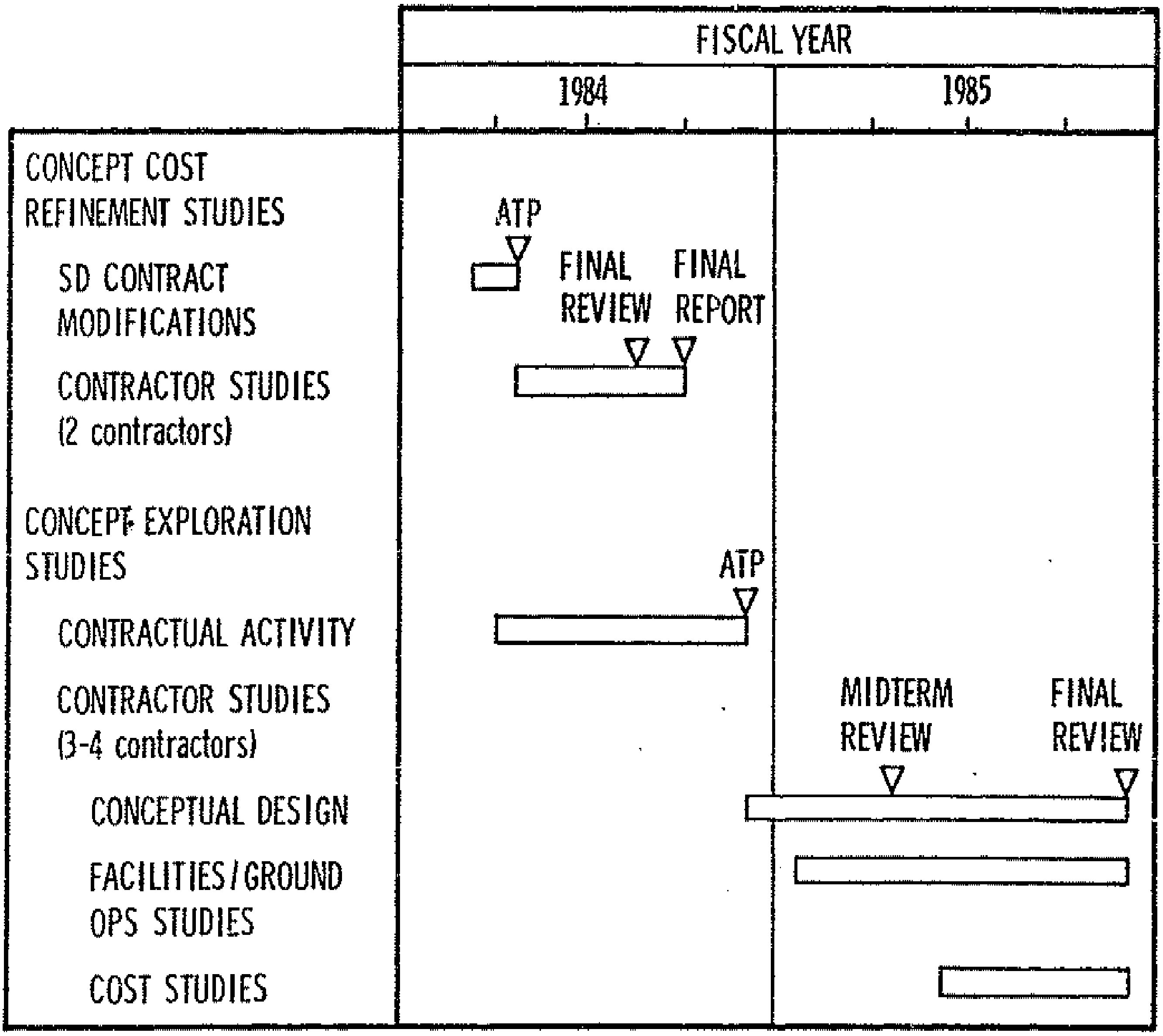


FIGURE AVI-2

ULV Development Program Flow

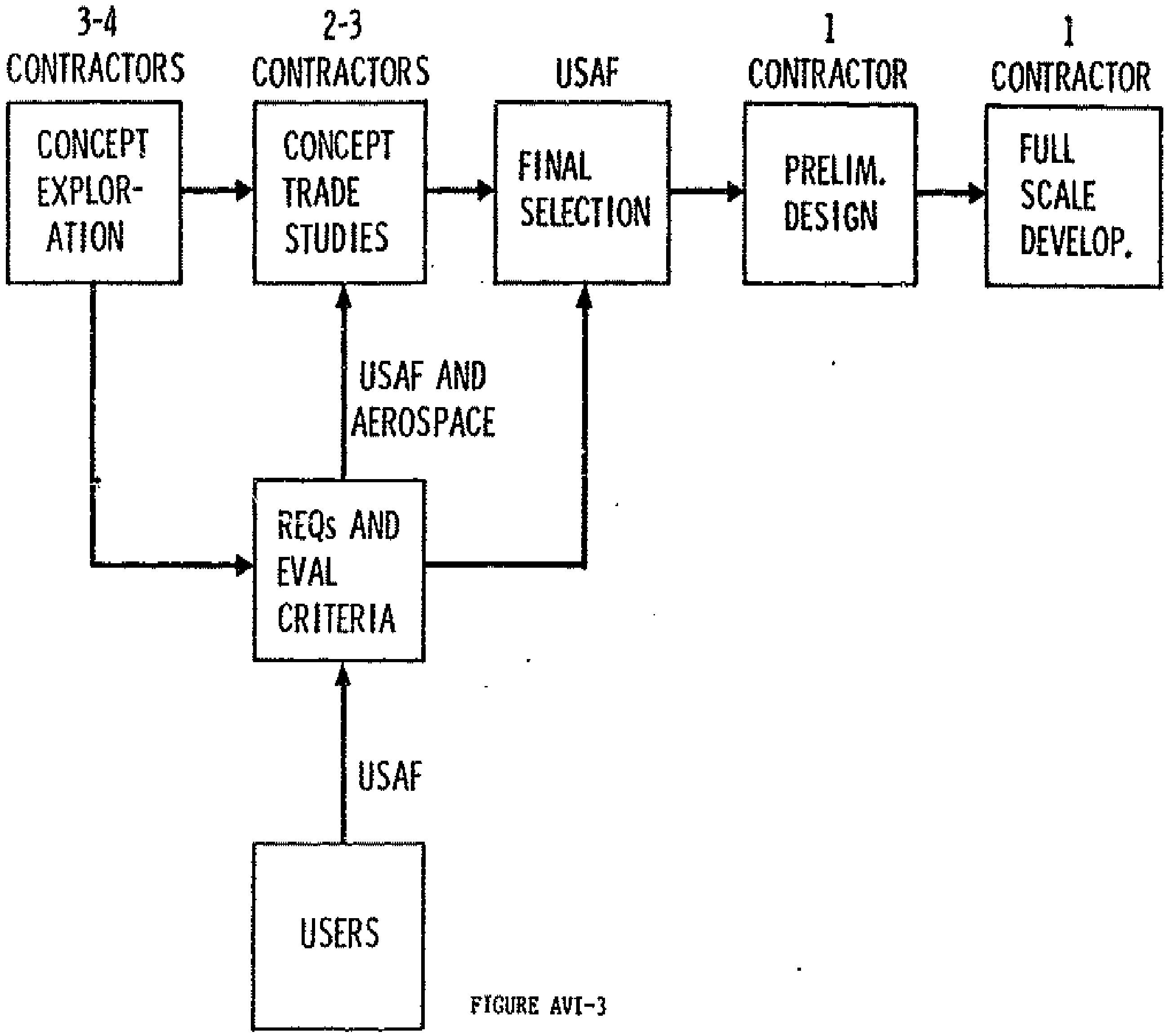


FIGURE AVI-3

ULV Program Costs

MILLIONS OF FY 83 DOLLARS

	FISCAL YEAR											
	84	85	86	87	88	89	90	91	92	93	94	95
DD&E[1]	0.6	3	8.4	20	107	342	514	513	385	235	43	
PRODUCTION[2]								25	160	125	115	19
FACILITIES (VAFB)					10	10	25	60	40	10		
TOTAL	0.6	3	8.4	20	117	352	539	598	585	370	158	19

TOTALS

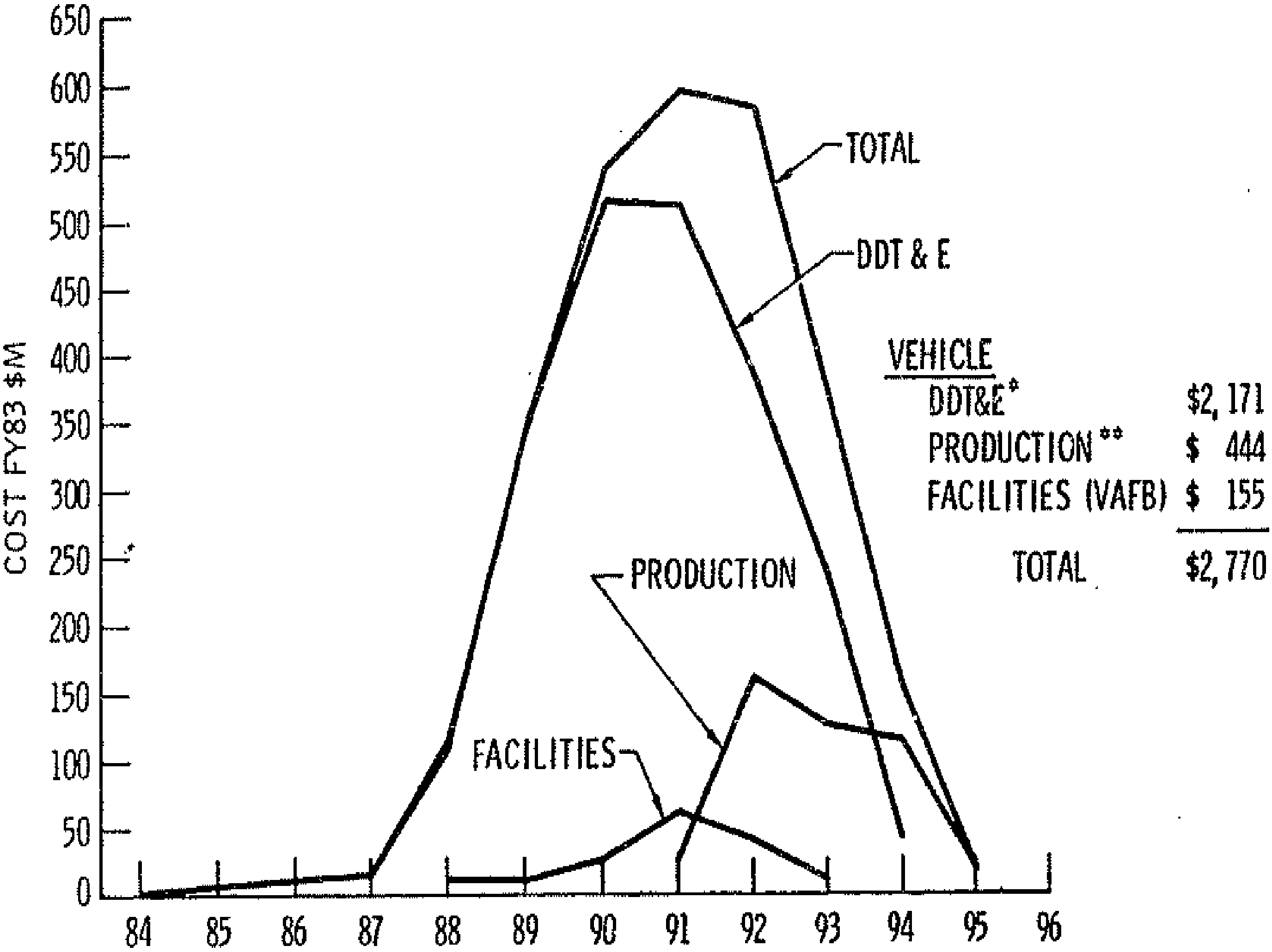
DDT & E	2171 M
PRODUCTION	444 M
FACILITIES	155 M
TOTAL	2770 M

1) Includes 2 propulsion/avionics and payload modules

2) One propulsion/avionics model only with spares

FIGURE AVI-4

ULV Program Costs



* INCLUDES 2 P/A MODULES

** INCLUDES 1 P/A MODULE + SPARES

FIGURE AVI-5

APPENDIX

1. Cost Estimating Procedure

Estimates for both non-recurring and recurring costs of ULV concepts were derived from the application of cost-estimating relationships (CERs), which in turn, were based on cost histories of previous launch vehicles, including the Shuttle. Accordingly, all such estimates assume typical programs with the typical kinds of problems encountered in such development and production projects. In addition to CERs, the actual cost of Shuttle system components was used as a basis for cost estimating whenever such components were included in a design (for example, the SSMEs and the SRB electronic controls). These cost estimates also assume that where the same Shuttle hardware components are used, the same contractors and suppliers are also utilized. Finally, it is assumed that no orbital flight tests are required for the ULV program and that test data would be provided by the first few operational flights (possibly flown with low-value payloads).

The actual steps in the cost estimating process are as follows. First, descriptive data including component quantities and unit weights are obtained for each major subsystem of a particular ULV concept. Next, a determination is made concerning the commonality of the Shuttle Orbiter, ET, SRB or other existing launch vehicle subsystems or components with the proposed design. For common items it is assumed that only follow-on costs would apply; that is, if 15 engine interface units (EIU) have been built for the Orbiter program and several EIUs per vehicle are required for the ULV program, then the ULV cost would be based on the unit cost of those items that follow the first 15 EIUs. Finally, for all subsystems and components that are peculiar only to the ULV the appropriate CERs are applied.

All ULV cost estimates presented here are preliminary in nature and based on the side-mounted ULV reference configuration. The in-line configuration non-recurring costs (DDT&E, production, and facilities) are expected to be similar and roughly equal to the side-mounted configuration costs. The cost of DDT&E for the in-line configuration should be similar to side-mount configuration costs because such items as a savings from a two SSME design would be offset by costs of ET modification and SSME propellant feedline changes. Production of P/A modules for the in-line should be slightly cheaper due primarily to the two SSME design. Facilities costs for the in-line could be greater due to the need to modify the Shuttle launch pads for use with an in-line vehicle. However, some of these modifications could be avoided by air-starting the SSMEs. The concept cost refinement studies currently being conducted will provide a greater depth of detail and fidelity to cost estimates for both ULV reference configurations.

APPENDIX

2. DDT&E Costs

The DDT&E cost of $2.2 billion is required for developing the P/A and P/L modules, with a small amount (about $10 million) for installing fixed de-orbit rockets on the ET (Figure AVI-6). The P/A module is the major development element, and is estimated to cost $1.9 billion (Figure AVI-7). The P/L module development is estimated at $220 million. The DDT&E cost estimates include ground support equipment (GSE), limited spares, test units, government support, and the SSMEs and avionics software required for the P/A module. The test units built for DDT&E include two P/A and P/L modules which will be used for the first two flights, after which the P/A modules will be refurbished and used as operational modules.

3. Production Unit Costs

The ULV total program cost includes approximately $450 million for the production of an additional operational P/A module (to provide a viable working fleet of three P/A modules). Preliminary cost estimates for this unit are broken out by major subsystem in Figure AVI-8. Production cost estimates do not include the cost of producing P/L modules, or the cost of modifying ETs for use with the ULV. These costs are included in ULV operations costs.

4. Facilities Costs

The ULV is designed to involve minimum modifications to STS launch facilities; however, differences between the ULV and the Space Shuttle, along with the larger cargoes of the ULV, require that some modifications be made. The reference side-mount vehicle configuration was used as the basis for determining modification costs. An in-line ULV configuration could result in significantly more costly modifications (possibly even up to $600 million) if it exceeded the launch pad capability at VAFB.

At VAFB the cost of the ULV facilities modifications would be approximately $150 million. Principal modifications would be the addition of a new CMIF to integrate the longer payloads, and an upper stage (Centaur) checkout facility. Other minor modifications would include new umbilicals, Launch Processing Systems software and access platforms.

Facilities modifications at KSC would be less extensive, requiring primarily a new CMIF with an attached P/A module refurbishment facility. As at VAFB, some minor modifications to umbilicals, software, and access platforms would be necessary. These would cost approximately $115 million. Only VAFB facility modification estimates are included in the total program cost, as the most probable USAF use of the ULV would be at VAFB.

ULV Component Development Cost Estimate

MILLIONS OF FY 83 DOLLARS

	P/A MODULE	PAYLOAD MODULE	ET MOD	OTHER	TOTAL
DDT&E	574	125	10	32	709
GROUND SUPPORT EQUIPMENT	43	4	-	-	47
ENGINES (incl test units)	285	-	-	-	285
TEST UNITS (less engines)	639	60	-	-	699
SPARES	19	2	-	-	21
SOFTWARE	100	-	-	-	100
GOVERNMENT SUPPORT	249	29	-	-	278
	1909	220	10	32	2171

FIGURE AVI-6

P/A Module Development Cost Estimate Detail

MILLIONS OF FY 83 DOLLARS

	PROPULSION	AVIONICS	SOFTWARE	TOTAL
DDT&E	451	123		574
GROUND SUPPORT EQUIPMENT	34	9		43
ENGINES (incl test units)	285			285
TEST UNITS	525	114		639
SPARES	16	3		19
SOFTWARE			100	100
GOVERNMENT SUPPORT	197	37	15	249
	1508	286	115	1909

FIGURE AVI-7

P/A Module Production Unit Cost Estimates

MILLIONS OF FY 83 DOLLARS

PROPULSION	276
ENGINES (3)	103
AVIONICS	65
	444

Notes: Propulsion and avionics cost estimate based on 1 production unit following 2 test units -- engine average cost estimated to be at Unit 40

FIGURE AVI-8

5. <u>ULV Operations Costs</u>

For conceptual purposes a very preliminary cost analysis of ULV operations was done using the STS cost data base as a departure point. It is important to understand the differences between STS and ULV element costs in order to appreciate their relative differences in operation costs. For example, the ULV ET costs are <u>more</u> than the STS ET costs. The difference is due to the inclusion of de-orbit rockets on the ULV ET, as it must be de-orbited with the payload module. The P/A module hardware is much <u>less</u> expensive than the Orbiter hardware as it is a fraction of the complexity and size. The ULV launch operations should be much simpler than the corresponding STS operations, although both use the same basic launch crew, because the ULV requires much less refurbishment and does not generally involve multiple payloads.

The result of the preliminary operations cost analysis showed the ULV costs to be sensitive to both scenario and flight rate for both the Shuttle and the ULV. Assuming a 24 flight rate per year for the Shuttle and a ULV flight rate of five per year, an estimated ULV flight will cost approximately $110 million in FY 83 dollars versus the corresponding $133 million Shuttle cost per flight.